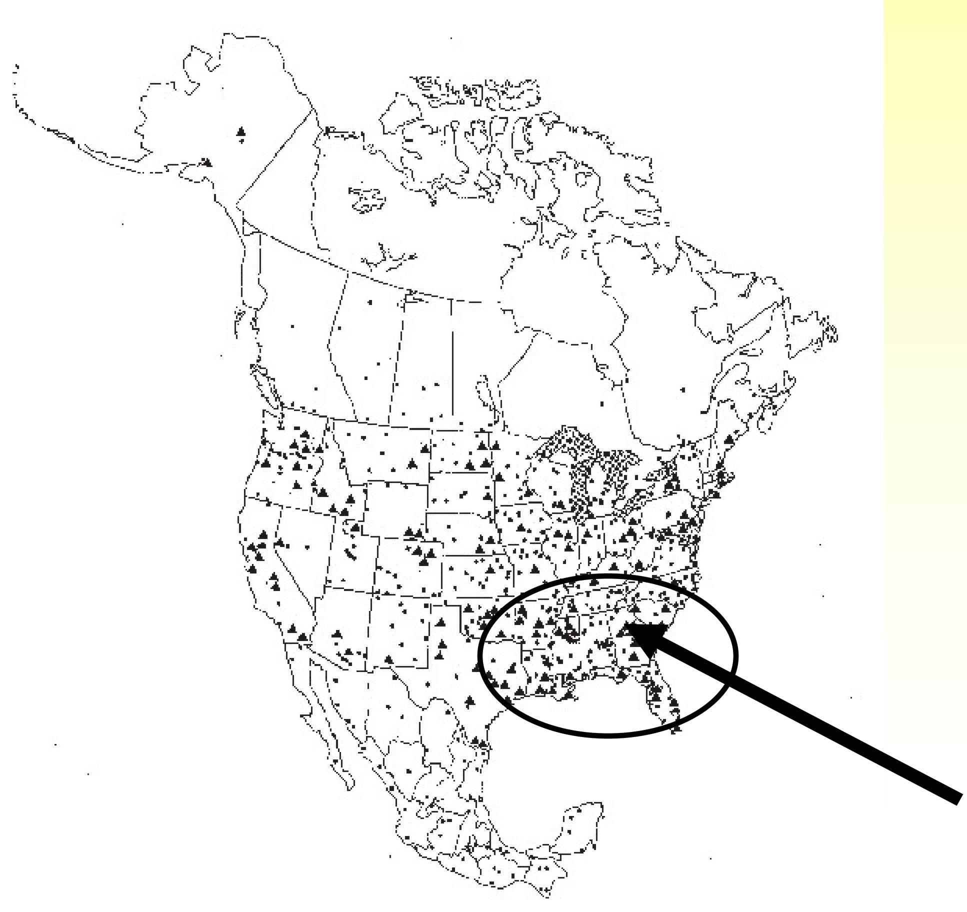
Opportunities to Mitigate Greenhouse Gas Emission from Agriculture in the Southeastern USA



Alan J. Franzluebbers

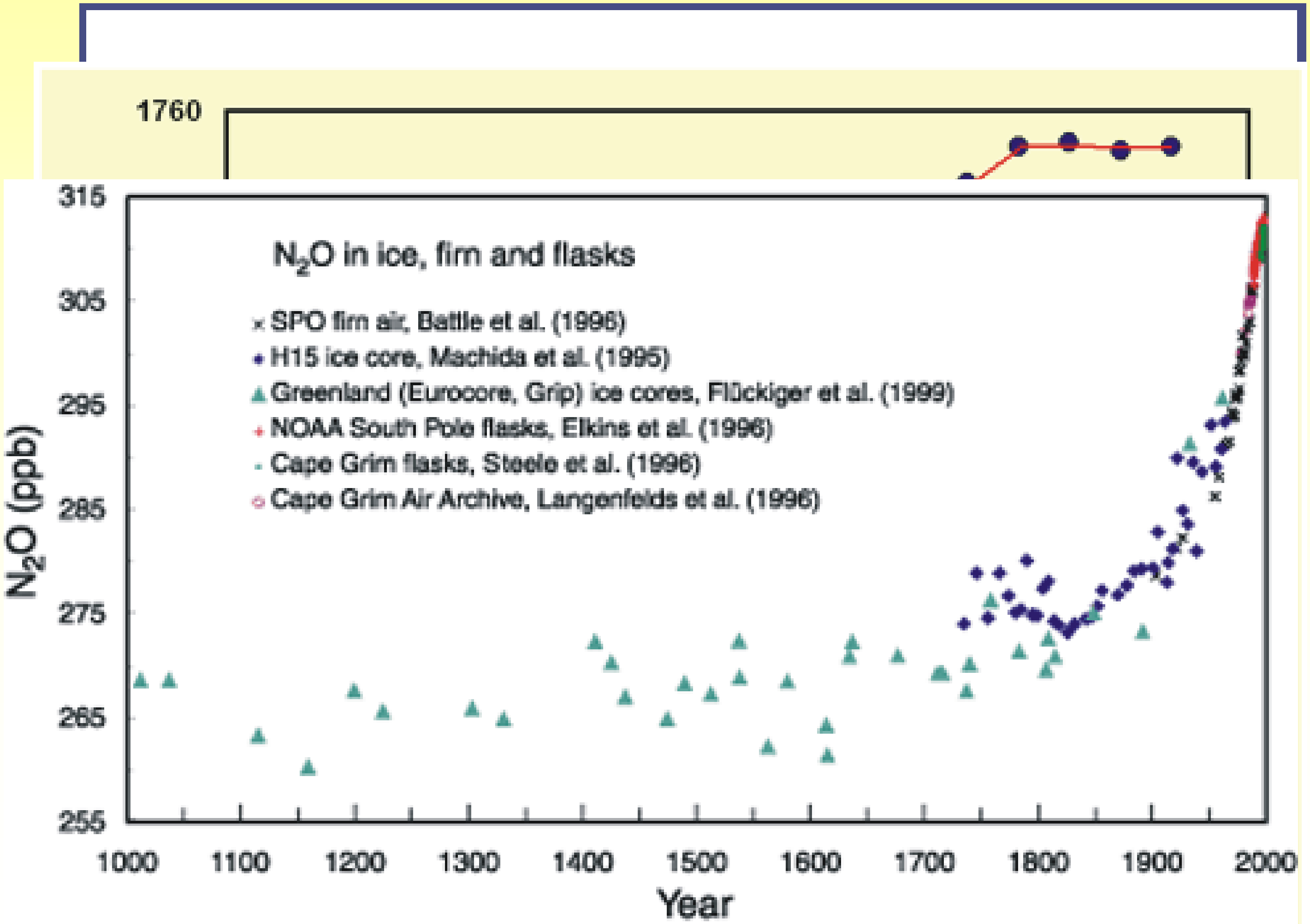
Ecologist

Watkinsville GA

Greenhouse Gases

✓What are they?

- Carbon dioxide (CO_2)
- Methane (CH_4)
- Nitrous oxide (N_2O)



Greenhouse Gases

✓ Why are they important?

- Increasing concentration in the atmosphere since 1750 (Intergovernmental Panel on Climate Change, 2001)
  - CO_2 – 31% increase
  - CH_4 – 151% increase
  - N_2O – 17% increase
- Cause radiative forcing of the atmosphere, which could alter global temperature and ecosystem functioning
- Can be manipulated by type of land management

Agricultural Role in GHG Emission

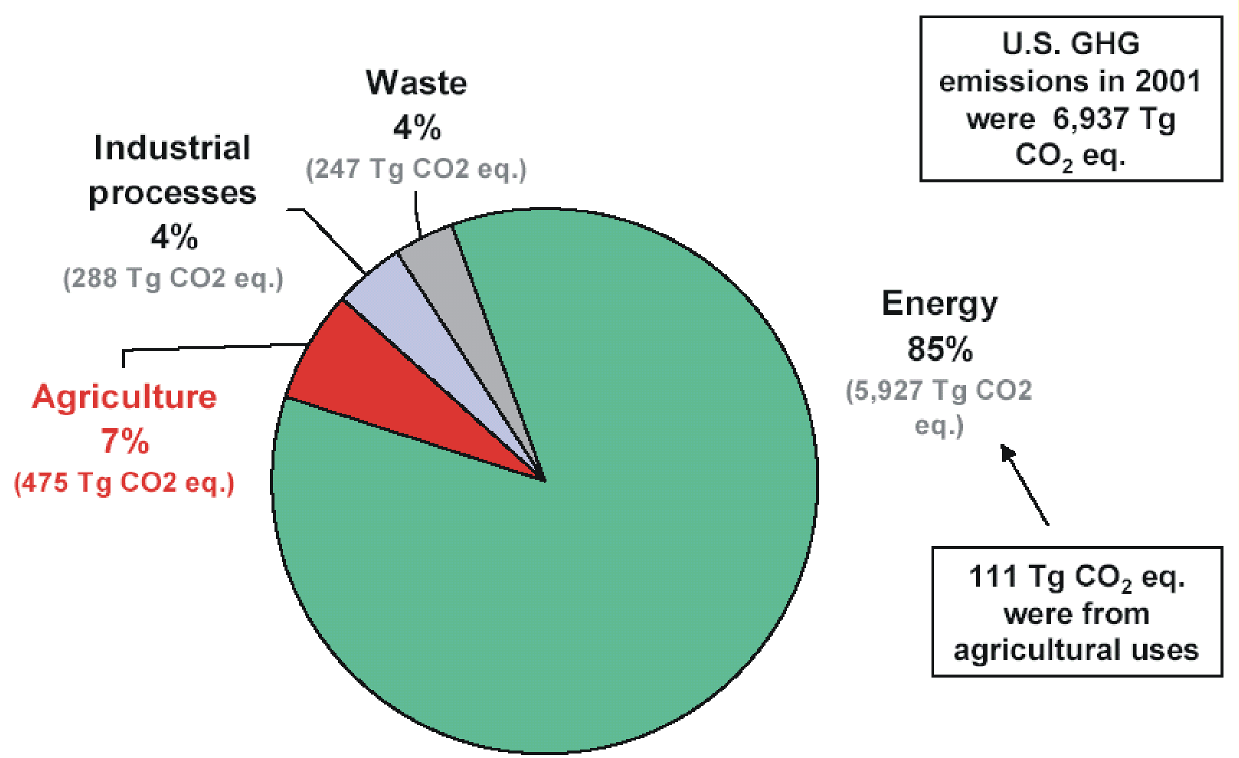
✓In the USA, <10% of total emission

Source of emission (global warming potential)

CO_2 (1)
- soil cultivation
- fuel use

CH_4 (21)
- anaerobic soil (rice)
- enteric fermentation
- livestock waste

N_2O (310)
- fertilization
- livestock waste

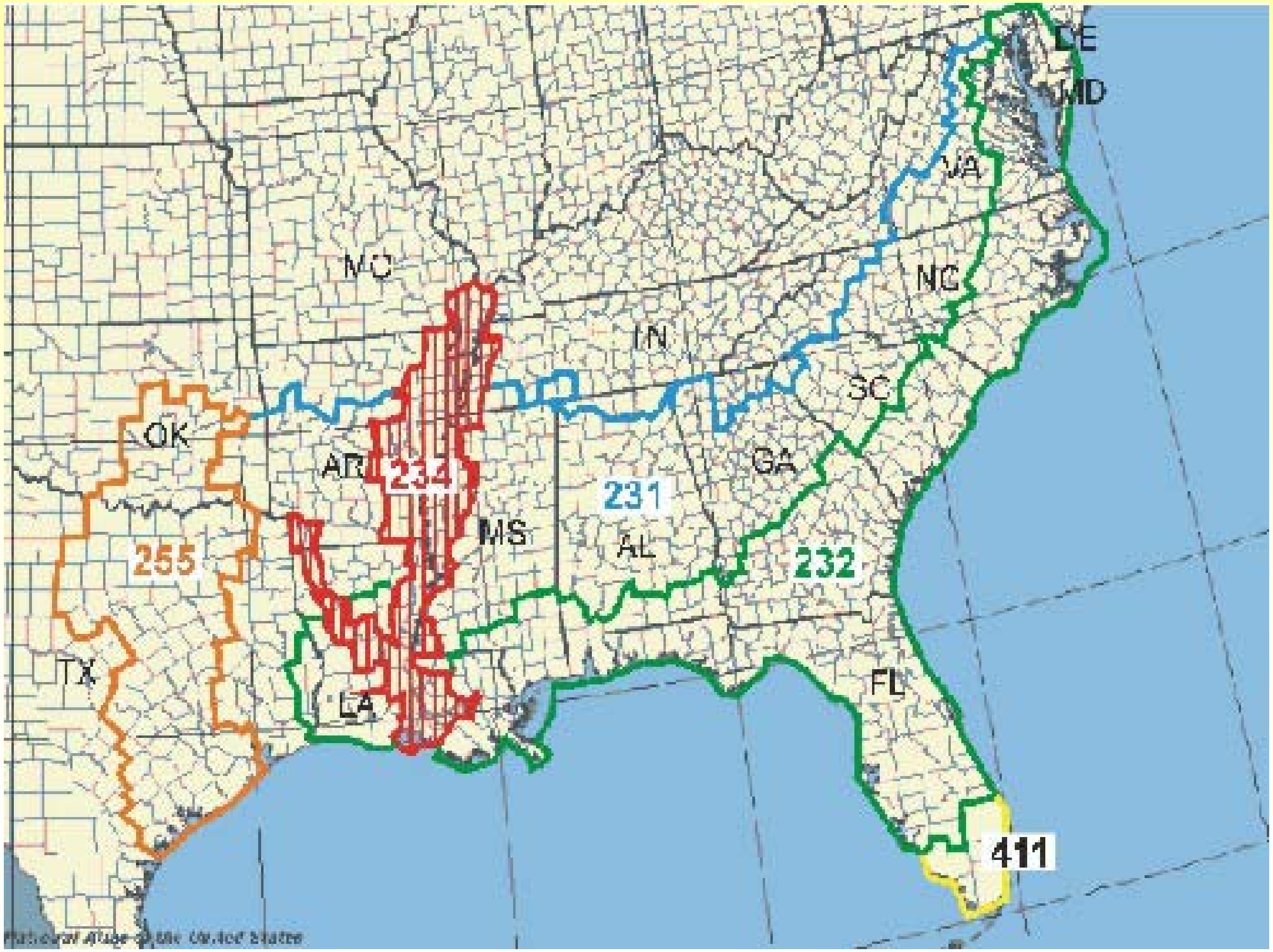


USDA (2004) U.S. Agric. & Forestry GHG Invent:1990-2001

The Southeastern USA

✓Geographic delineation (Bailey, 1995; Ecoregions of the USA)

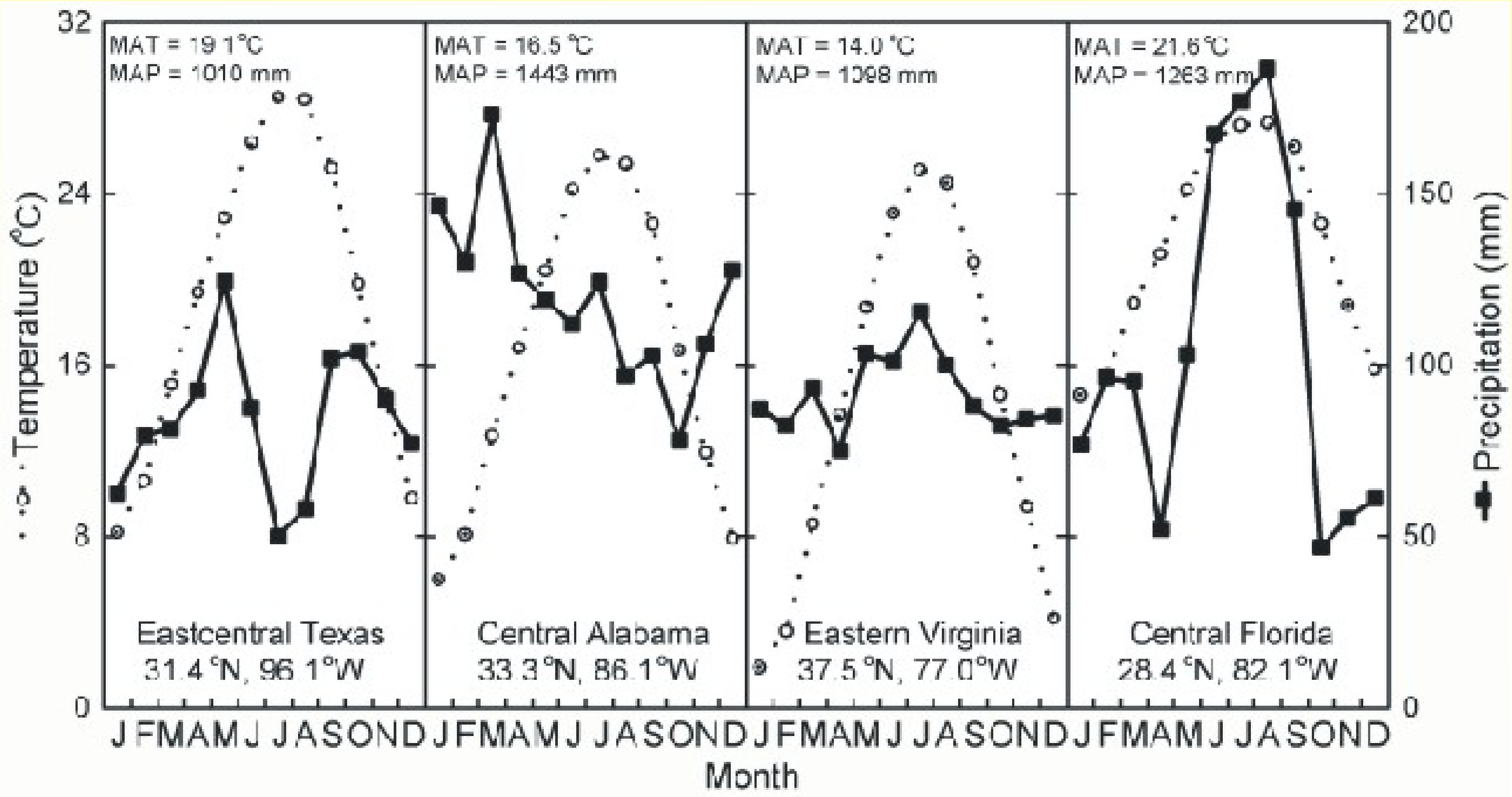
- AL
- AR
- DE
- FL
- GA
- LA
- MD
- MS
- NC
- SC
- VA



The Southeastern USA

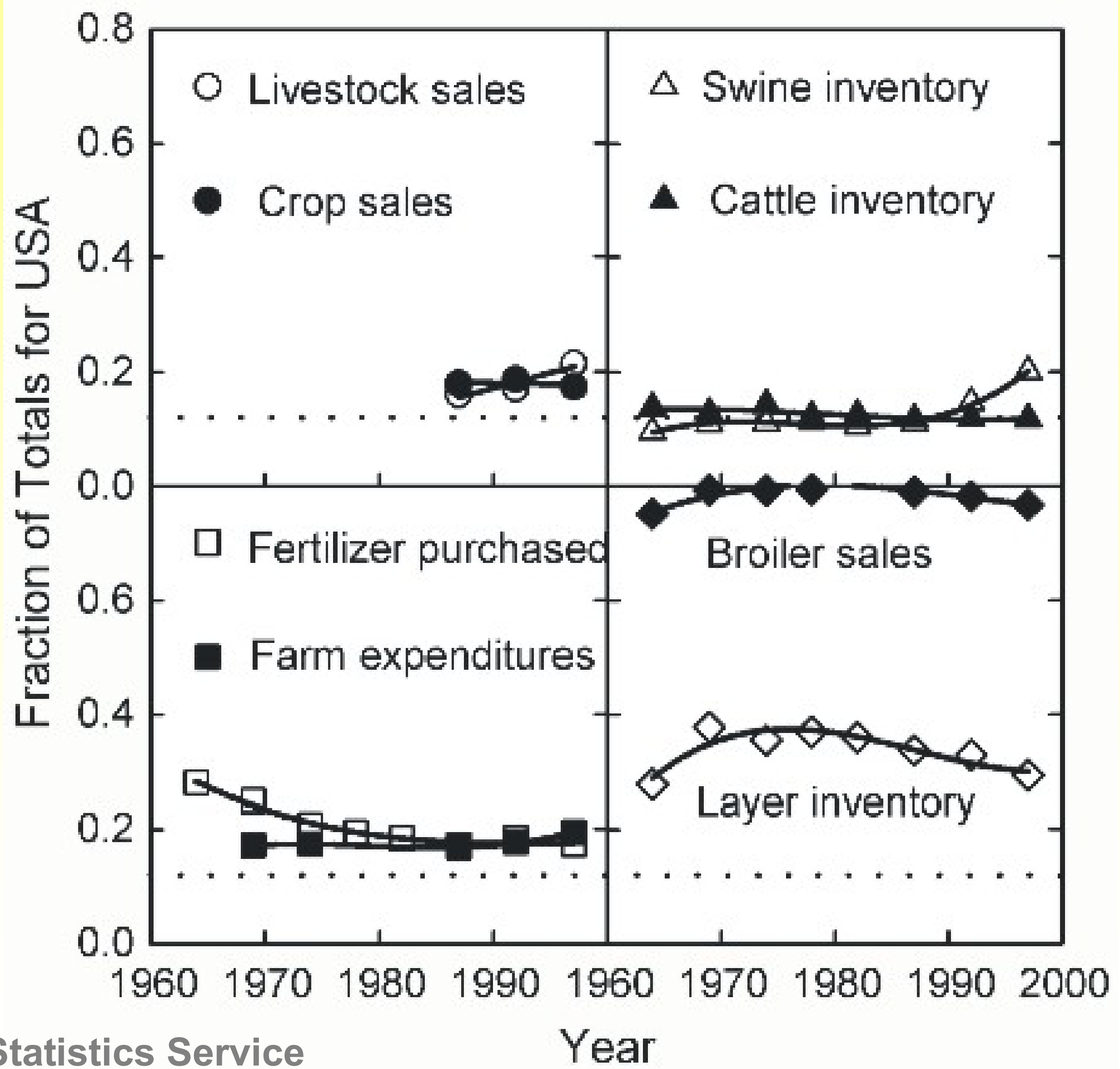
✓Climatic conditions

National Climatic Data Center



The Southeastern USA

- ✓ Agricultural production characteristics
  - Fraction of national totals during past 40 years
  - Dotted line is fractional land area of nation in the southeastern USA

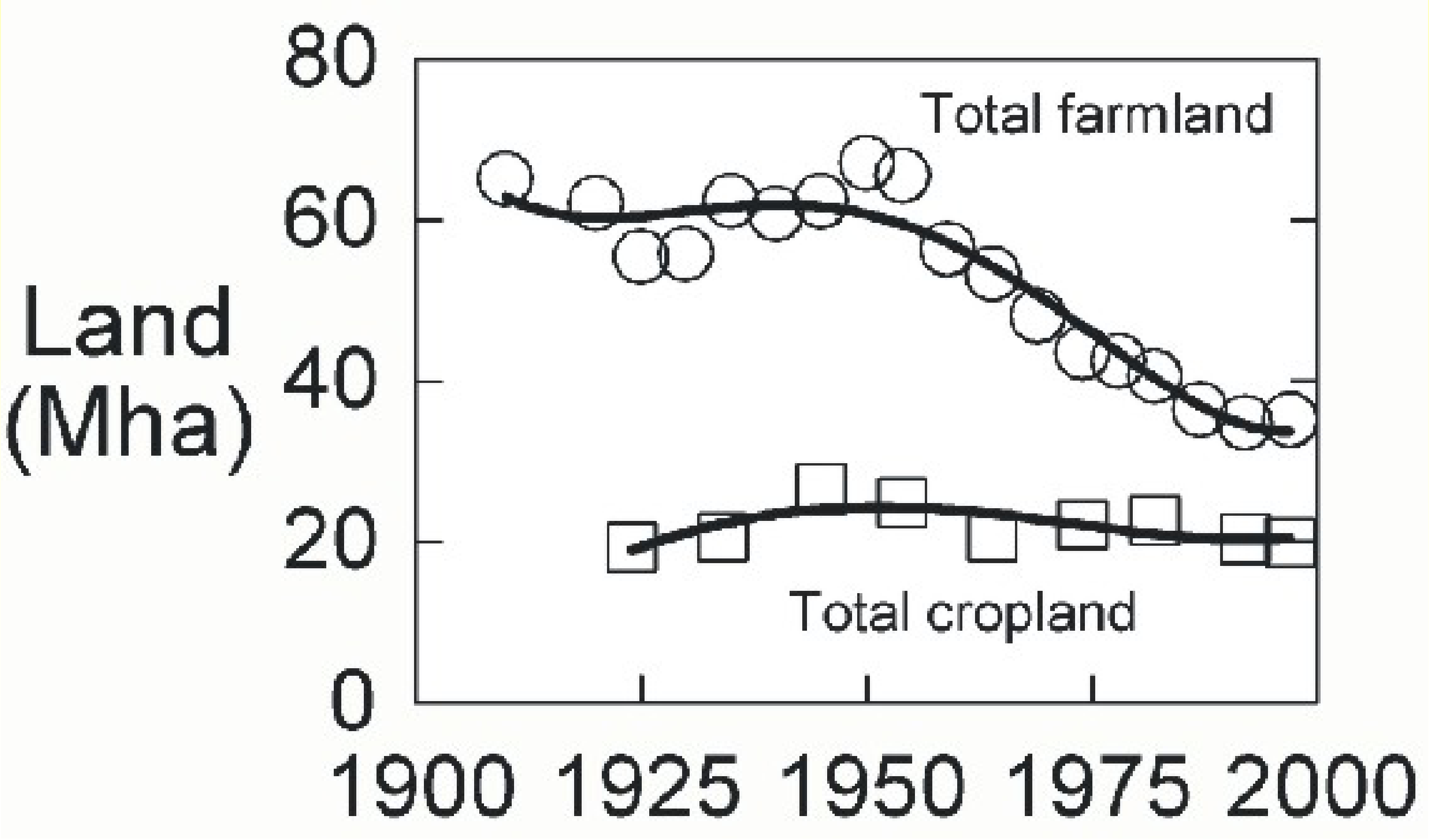


USDA-National Agricultural Statistics Service

The Southeastern USA

✓Agricultural production characteristics (last 100 yr)

USDA-National Agricultural Statistics Service



The Southeastern USA

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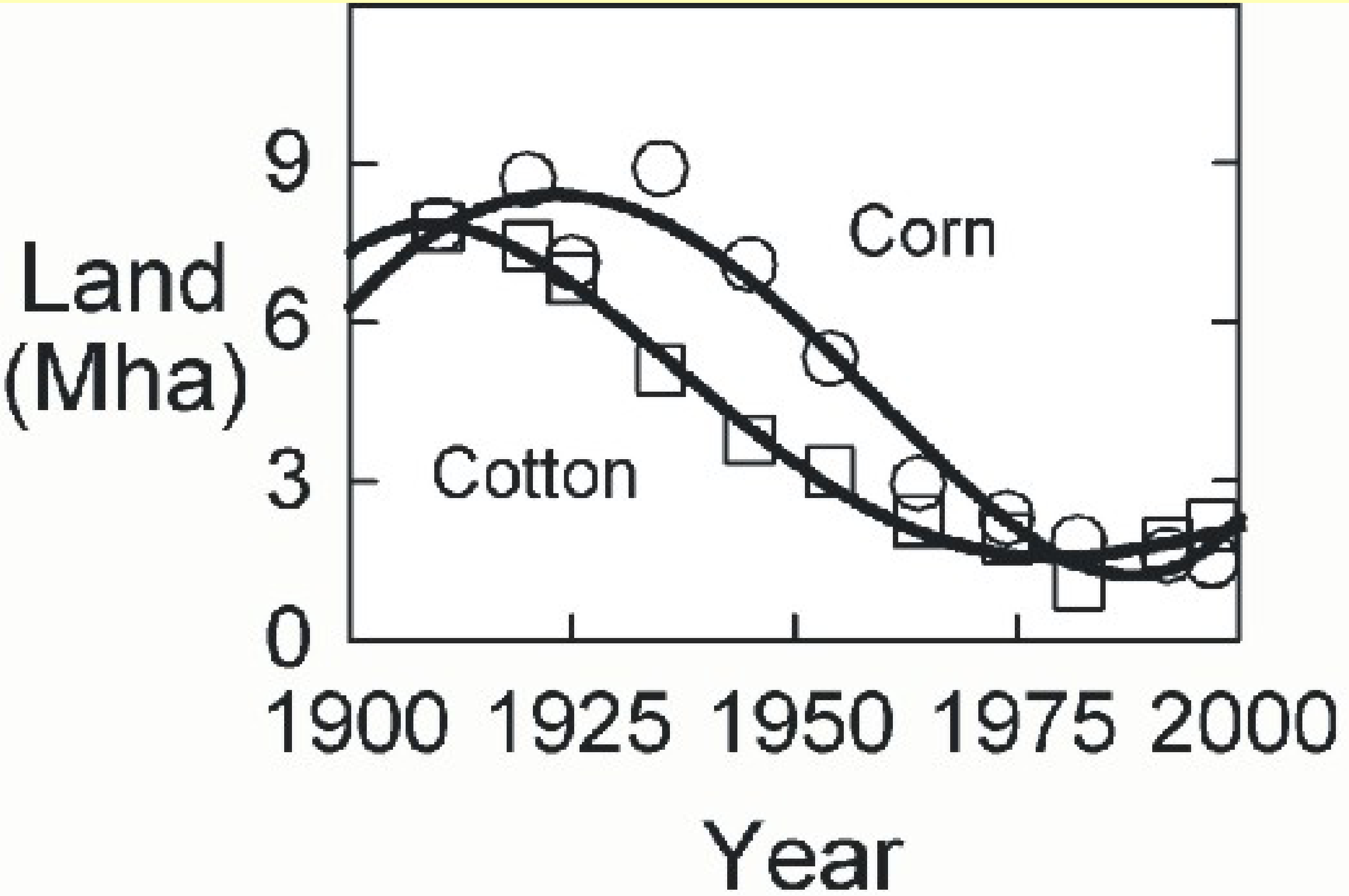
USDA-National Agricultural Statistics Service



The Southeastern USA

✓ Agricultural production characteristics (last 100 yr)

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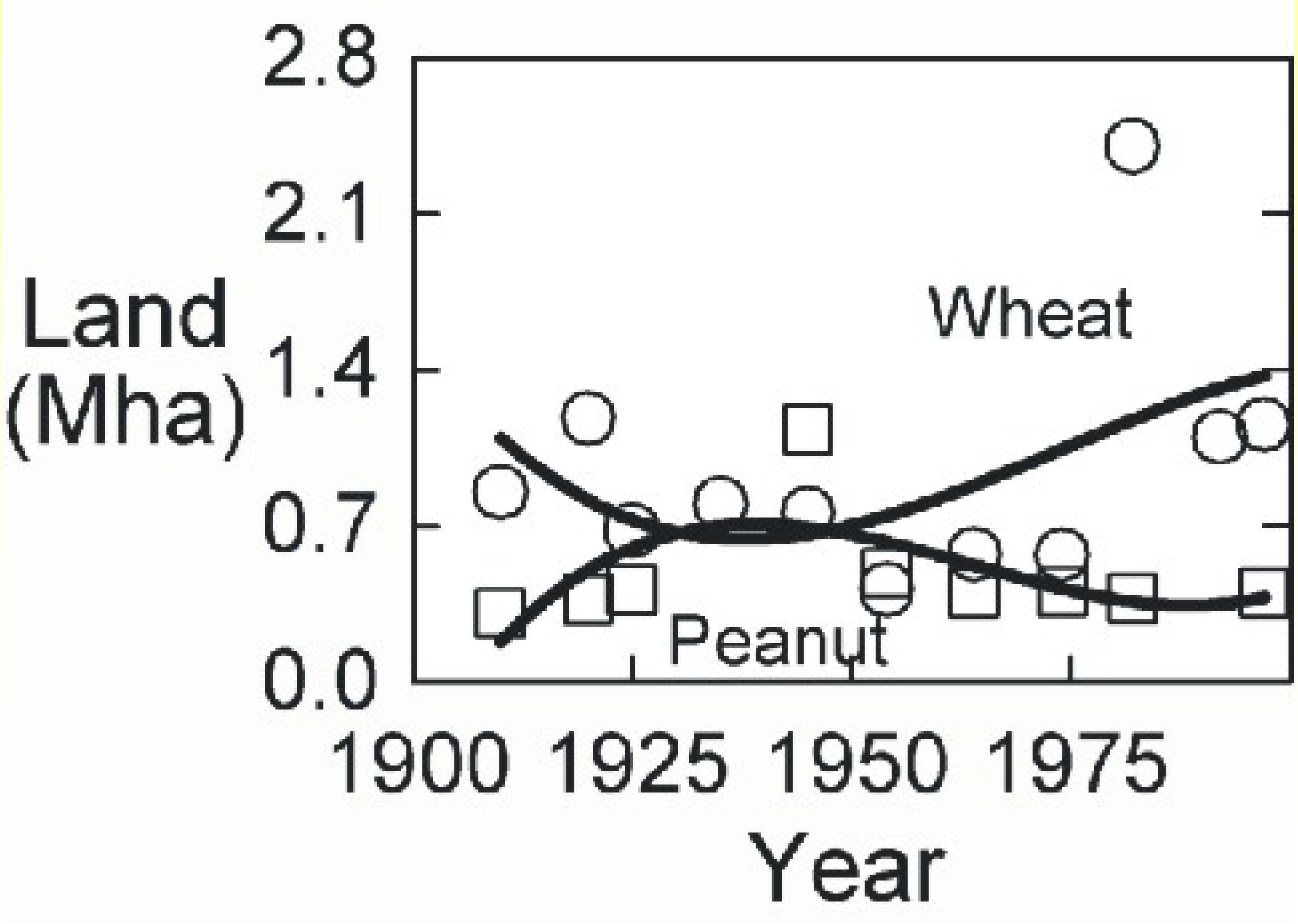

The Southeastern USA

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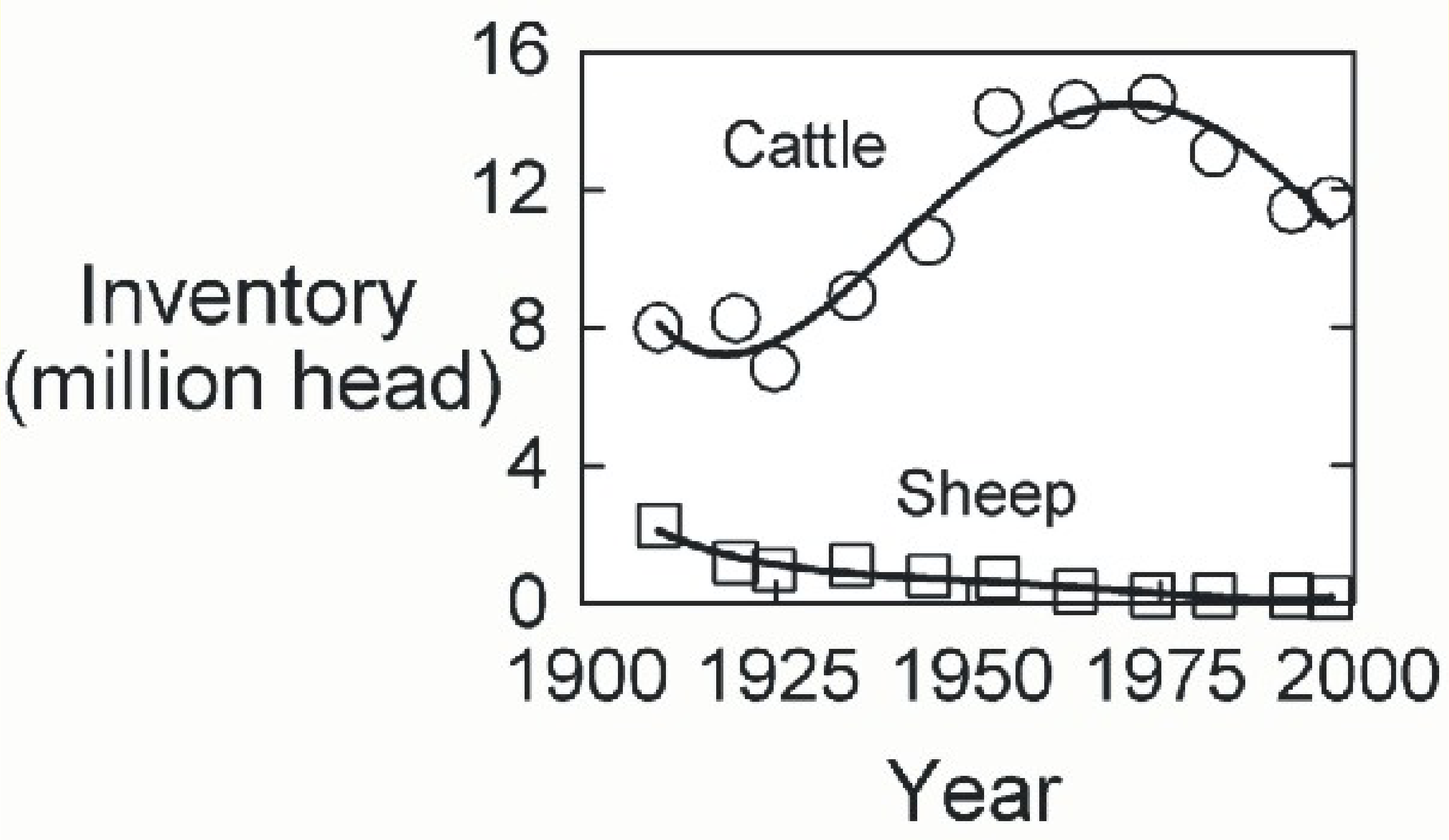
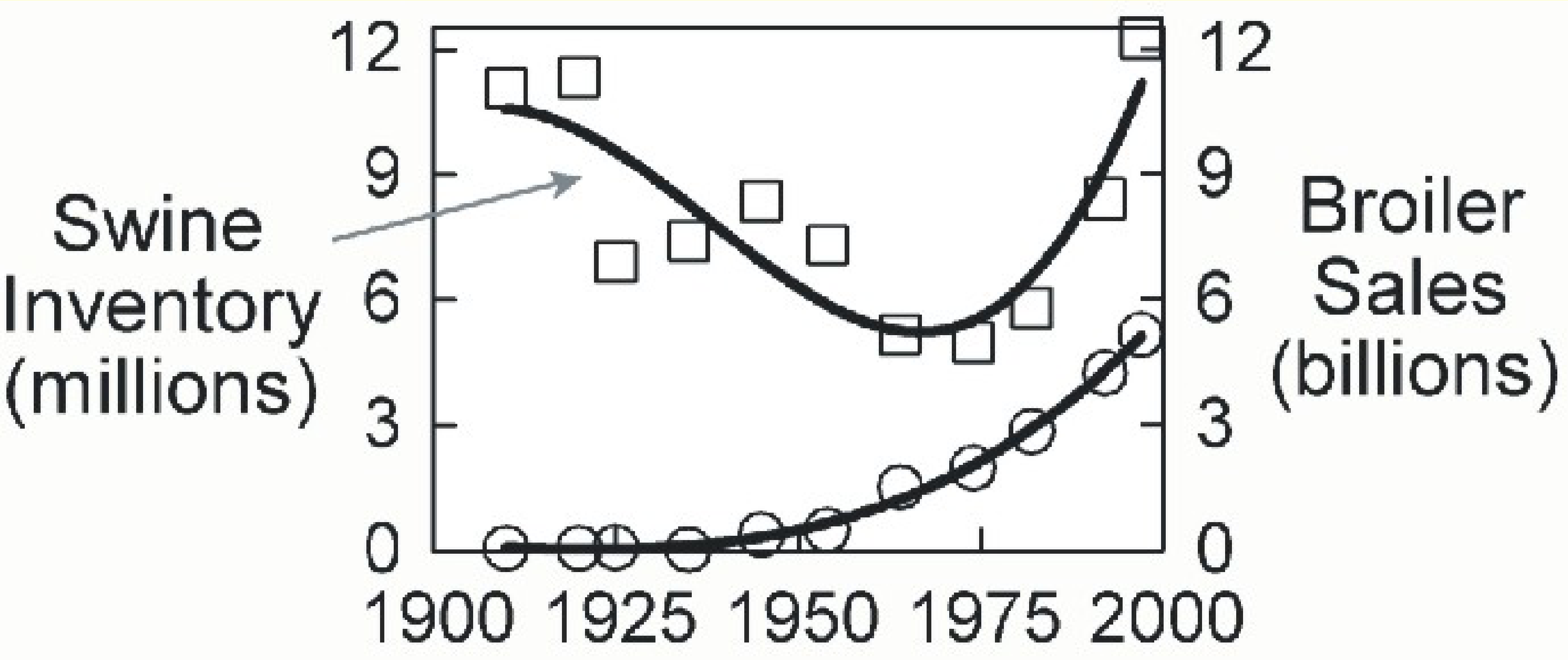


The Southeastern USA

- Agricultural production characteristics (last 100 yr)

USDA-National Agricultural Statistics Service

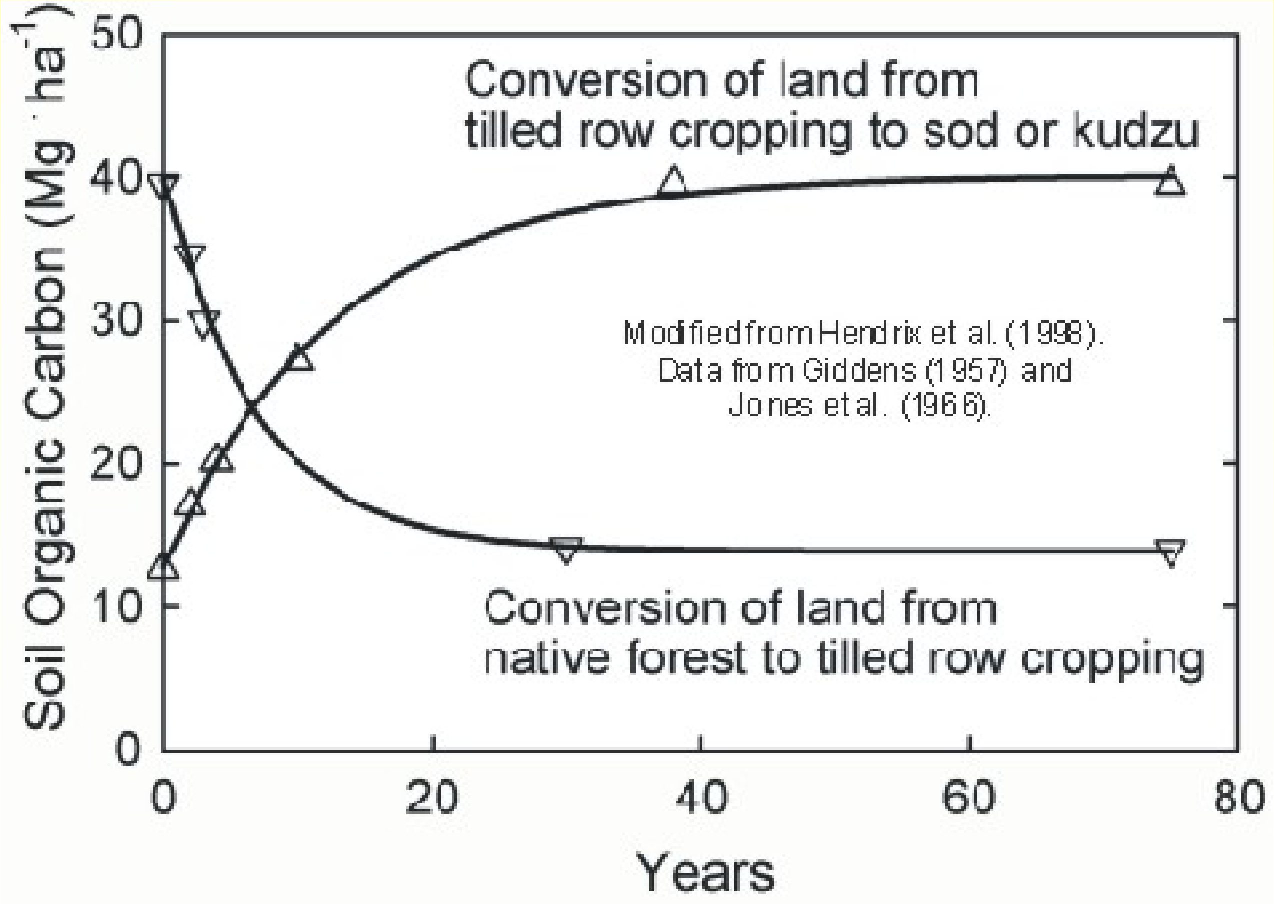


Agricultural Mitigation Strategies

- ✓ Increase soil organic carbon sequestration
  - Conversion of land to less disturbed usage
  - Conservation tillage
  - Pasture development
- ✓ Reduce fossil fuel use
  - Tractor time
  - Grain drying
  - Irrigation
- ✓ Reduce nitrogen fertilizer saturation
  - Reduce opportunities for nitrous oxide emission
- ✓ Increase cropping intensity
  - Sequester more C per unit of input costs

Land Use

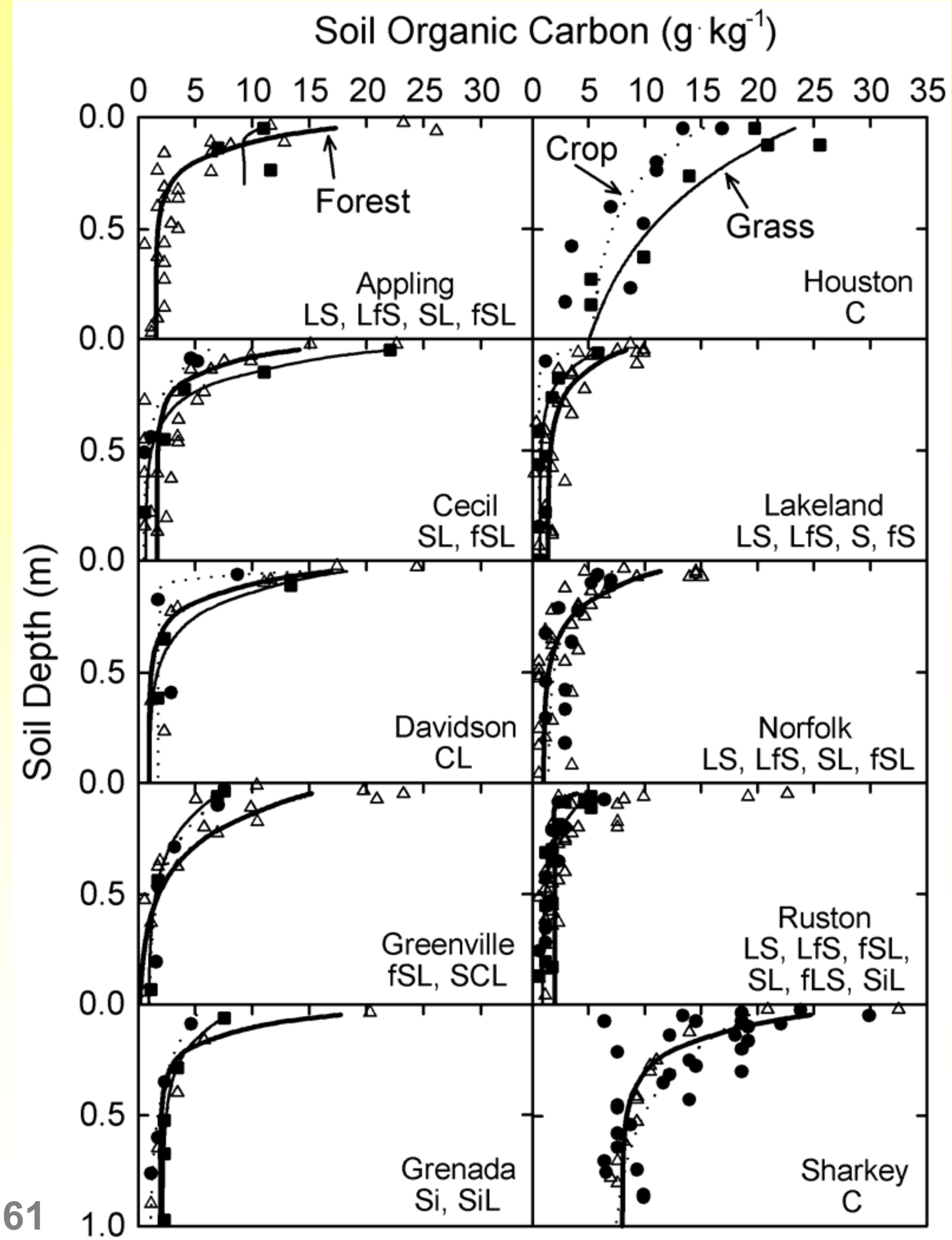
✓ Conversion of forest to conventionally tilled cropland can reduce SOC by ≥50%



Land Use

- ✓ Under forest and grass, soil organic C is typically stratified with depth.

- ✓ Below 0.5 m, soil organic C is typically <5 g kg^{-1}, except in high-clay-content soils.



McCracken (1959) South. Reg. Bull. 61

Land Use

✓Synthesis of available literature

Soil depth: 23 ± 5 cm

Soils: Ultisols (15), Vertisols (4), Alfisols (2), Inceptisols (2), Entisols (1)

Land use	Soil Organic C	No. observations
	Mg ha^{-1}	
Crop	31.1	27
Grass	47.4	25
Forest	49.9	15

Forest = Grass > Crop

Franzluebbers (2005) Soil Till. Res.

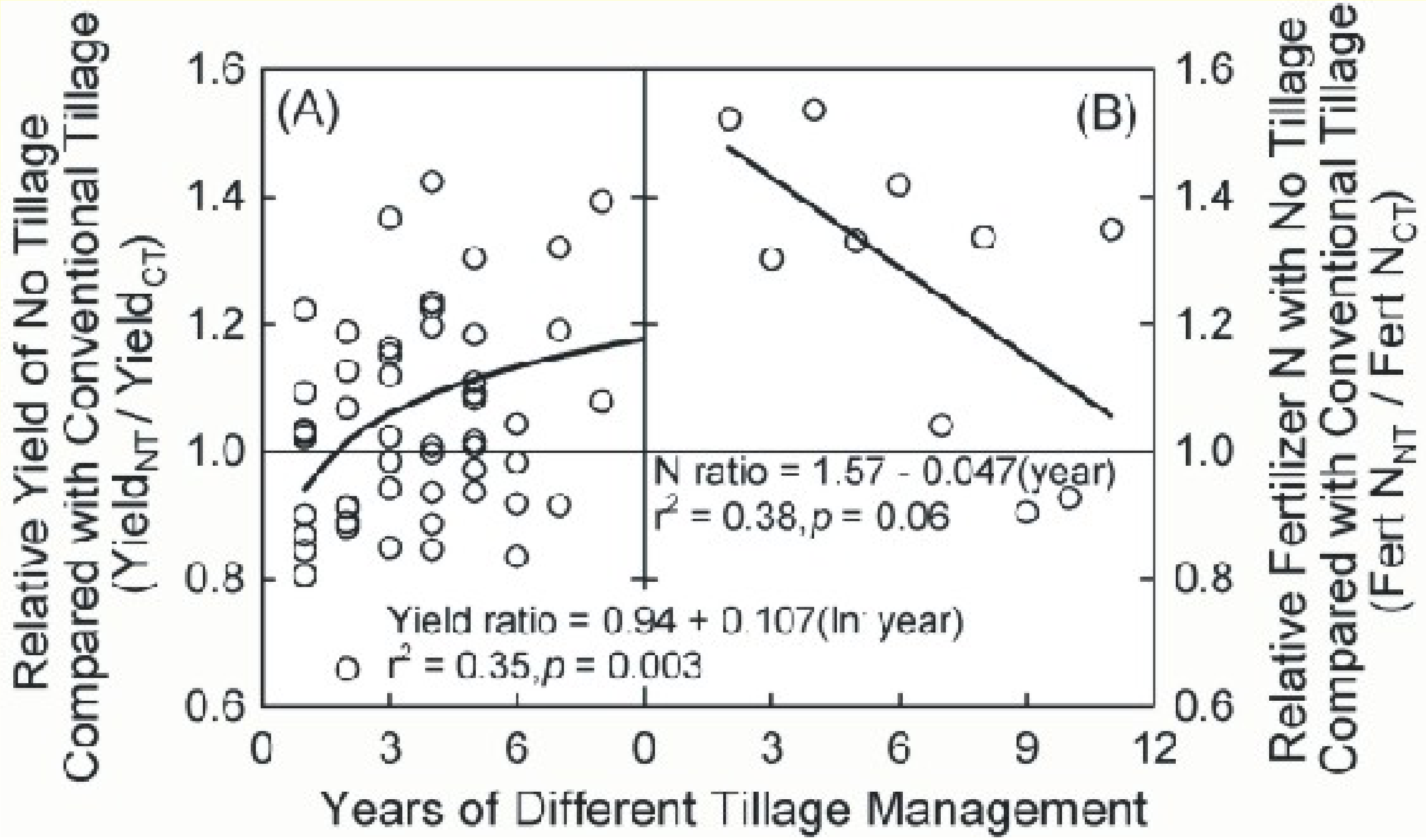
Conservation-Tillage Cropping

Crop (no. pairs)	Yield (Mg ha^{-1}) CT		NT
Corn grain (19)	6.8		7.1
Corn silage (5)	15.3		16.1
Corn stover (3)	7.4	<	8.8
Cotton lint (18)	1.0		1.1
Cotton seed (9)	2.6	<	2.7
Peanut seed (6)	3.4		3.4
Sorghum grain (8)	4.5		4.3
Soybean seed (18)	2.1		2.1
Wheat grain (9)	3.0		3.1
Overall (95)	5.1	<<<	5.4

Franzluebbers (2005) Soil Till. Res.

Conservation-Tillage Cropping

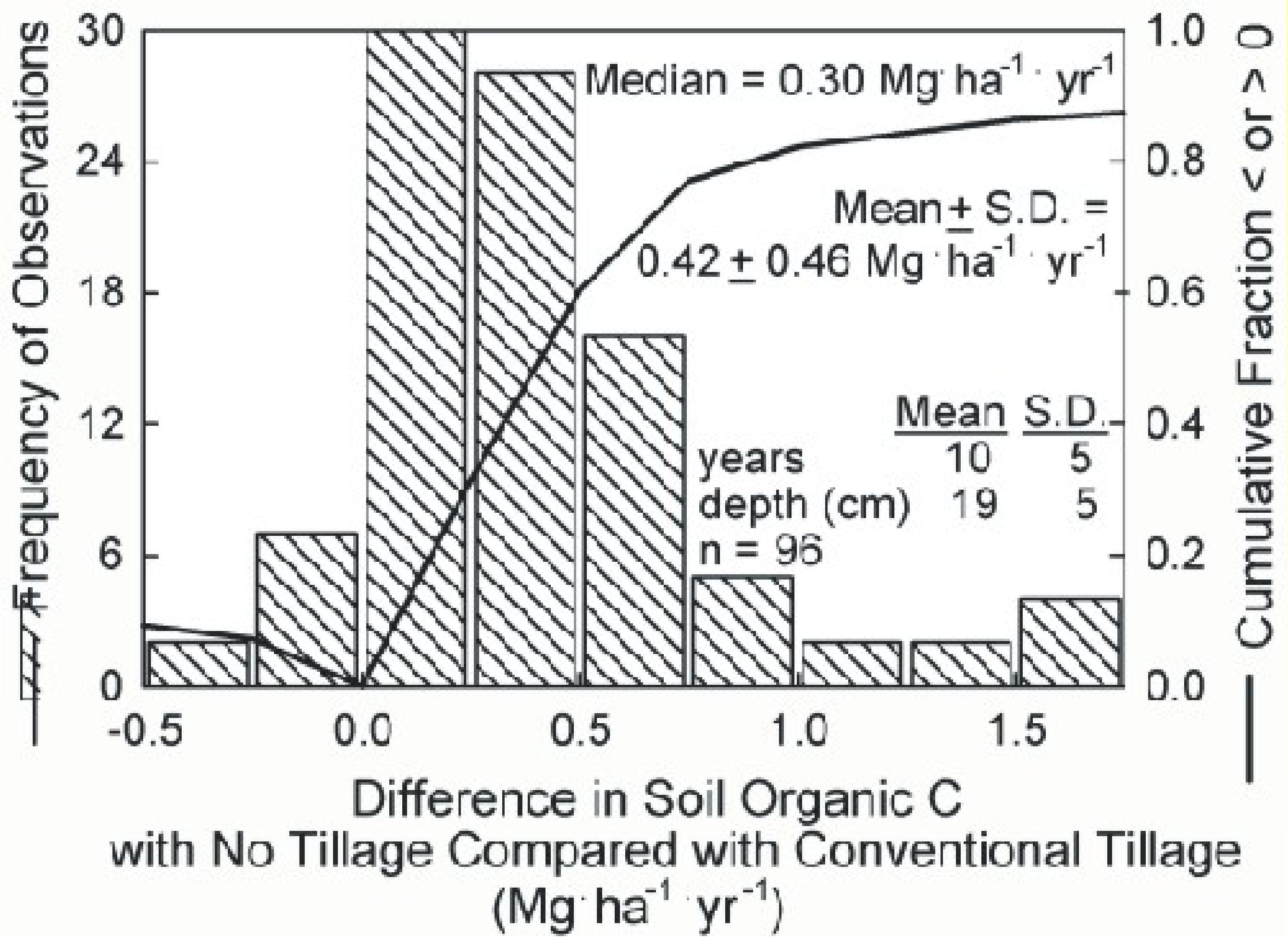
✓Long-term conservation-tillage cropping changes soil ecosystem functioning



Franzluebbers (2005) Soil Till. Res.

Conservation-Tillage Cropping

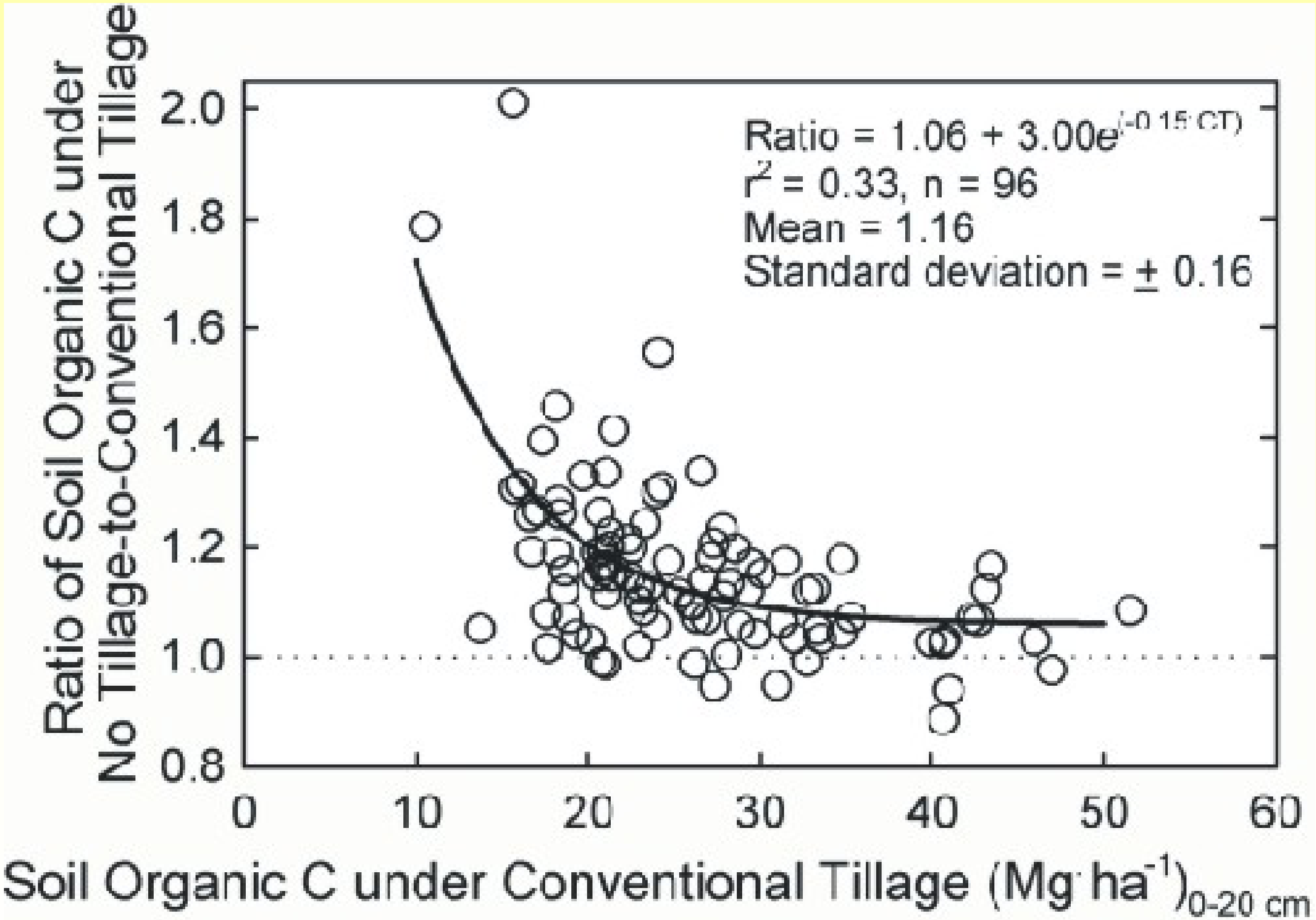
✓Compilation of literature in the southeastern USA



Franzluebbers (2005) Soil Till. Res.

Conservation-Tillage Cropping

- ✓ Initial soil organic C level impacts relative effect of NT



Franzluebbers (2005) Soil Till. Res.

Conservation-Tillage Cropping

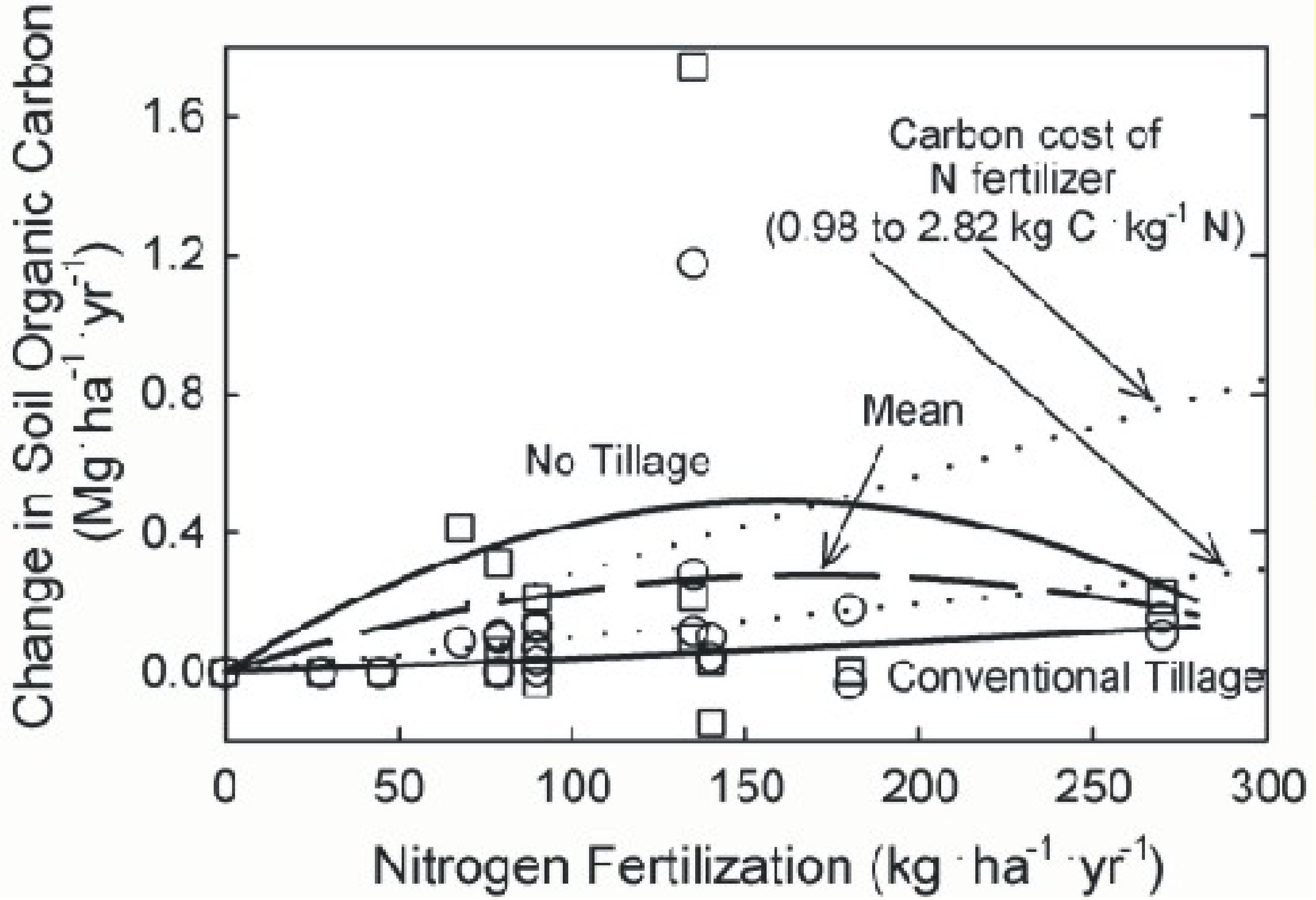
✓Cover cropping with NT enhances sequestration

Property	Cover Crop Without		Cover Crop With
Number of observations	40		53
Duration of comparison (yr)	12	**	9
SOC sequestration with NT (Mg ha^{-1})	2.5	**	3.9
SOC sequestration with NT (Mg ha^{-1} yr^{-1})	0.28	**	0.53
Ratio of SOC_{NT} : SOC_{CT}	1.11	*	1.20

Franzluebbers (2005) Soil Till. Res.

Conservation-Tillage Cropping

✓Nitrogen fertilization improves SOC sequestration, but not necessarily net global warming potential



Franzluebbers (2005) Soil Till. Res.

Pastures

✓ Grass establishment affects soil organic C

Effect of grass establishment	
Number of studies	12
Duration of comparison (yr)	15 ± 17
SOC sequestration (Mg ha^{-1} yr^{-1})	1.03 ± 0.90

✓ Rate of SOC sequestration was 2.5 times greater than with NT cropping

Franzluebbers (2005) Soil Till. Res.

Pastures

✓Cattle grazing affects soil organic C

Effect of harvest management	SOC ($Mg\ ha^{-1}$) Hayed	SOC ($Mg\ ha^{-1}$) Grazed
15-19-yr-old bermudagrass	31.2 $\pm$ 5.4	38.0 $\pm$ 8.6
5-yr-old bermudagrass	38.1 $\pm$ 2.4	42.1 $\pm$ 0.8
SOC sequestration ($Mg\ ha^{-1}\ yr^{-1}$)	0.76 + 0.60	

✓ Greater SOC with grazing was likely due to the return of dung to soil, while haying removed forage from land.

Franzluebbers (2005) Soil Till. Res.

Pastures

✓Poultry manure affects soil organic C

	SOC ($Mg\ ha^{-1}$)	
Effect of manure application	Without	With
2-yr studies (n=6)	19.8 ± 8.9	19.6 ± 8.4
11 ± 8-yr studies (n=8)	30.6 ± 11.4	36.8 ± 10.6
SOC sequestration for all ($Mg\ ha^{-1}\ yr^{-1}$)	0.26 ± 2.15	
SOC sequestration for >2-yr studies	0.72 + 0.67	

✓ Conversion of C in poultry litter to SOC was 17 ± 15%.

✓ Manure application transfers C from one land to another.

Franzluebbers (2005) Soil Till. Res.

Trace-Gas Emissions

- Nitrous oxide
  - Limited data available

Study	Control	Poultry Litter
	Nitrous oxide emission (kg N_2O-N ha^{-1})	
Marshall et al. (2001) Nutr. Cycl. Agroecosys. 59: 75-83		
Coastal Plain (AL)	6.3	4.9
Piedmont (GA)	0.3	1.9
Cumberland Plateau (TN)	1.9	1.5
Thornton et al. (1998) Atmos. Environ. 32:1623-1630		
Tennessee Valley (AL)	0.5	3.9
	urea 3.0	composted 1.6
Groffman (1985) Soil Sci. Soc. Am. J. 49:329-334		
Athens GA (cropping system)	CT 579	NT 505
Walker et al. (2002) Chemosphere 49:1389-1398		
Dillard GA (riparian forest)	grazed 25	ungrazed 24

Trace-Gas Emissions

✓ Methane

- Flux estimates in other regions indicate potential for soil with high organic matter to act as a sink for CH_4
- No data on soil CH_4 uptake in the southeastern USA

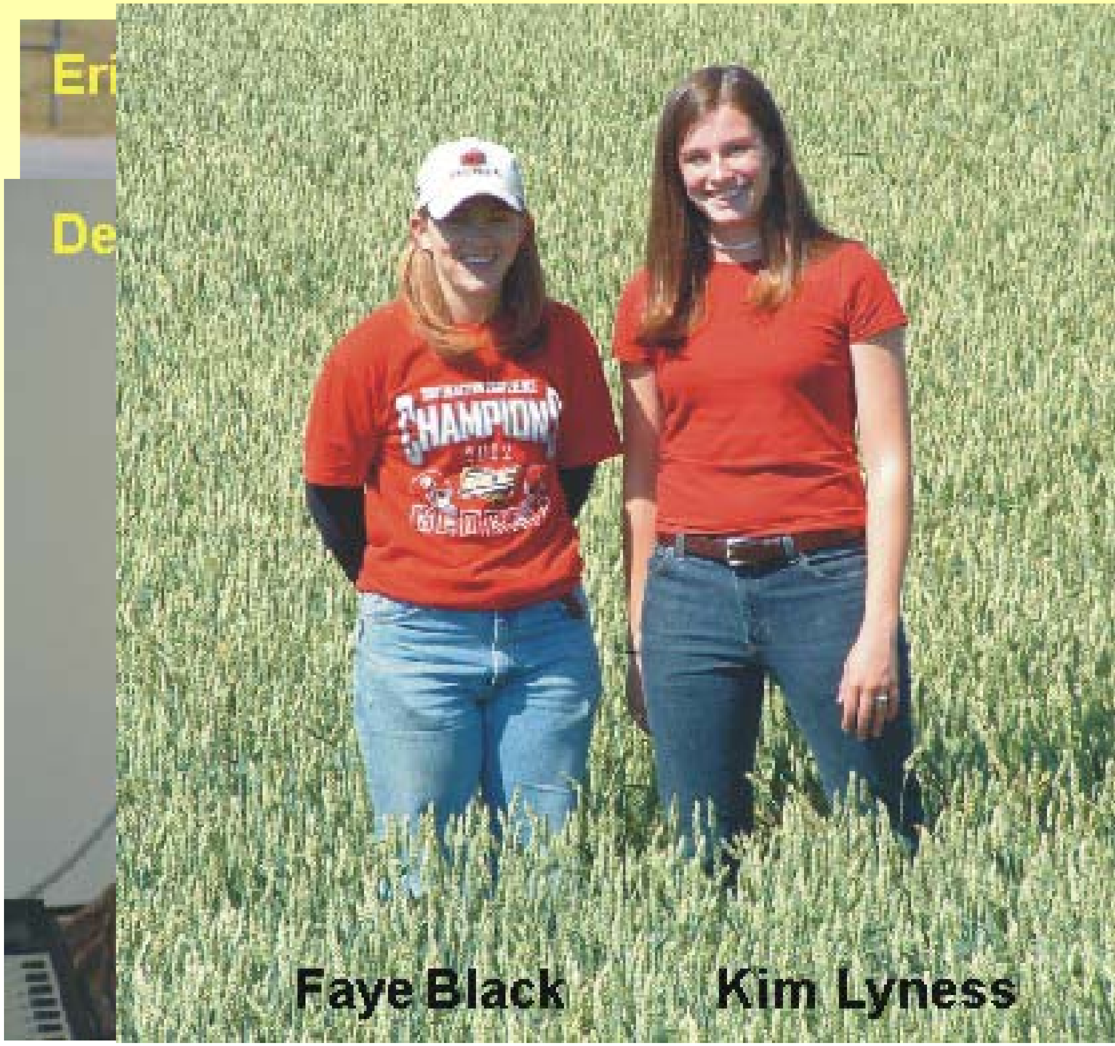
Harper et al. (2000) J. Environ. Qual. 29:1356-1365

Cordele GA (swine confinement, micrometeorological assessment)

Lagoon	Total gas flux	N_2	CO_2	N_2O	CH_4
	kg ha^{-1} d^{-1}	---------------	%	---------------	
First (3.5 ha)	159	15	5	0	79
Second (1.3 ha)	21	54	2	0	26
Third (3.5 ha)	20	59	1	3	13
Fourth (1.3 ha)	17	69	1	18	8

On-Going Studies in Watkinsville

✓Research team



On-Going Studies in Watkinsville

- ✓ Salem Road grazing study, Farmington GA
- ✓ Phase 1: 1994-1998, ‘Coastal’ bermudagrass
- ✓ Phase 2: 1999-2005, interseeded ‘Georgia 5’ tall fescue
- ✓ 4 harvest regimes
  - Hayed
  - Low forage mass
  - High forage mass
  - Unharvested

Full

↕ Forage utilization

None

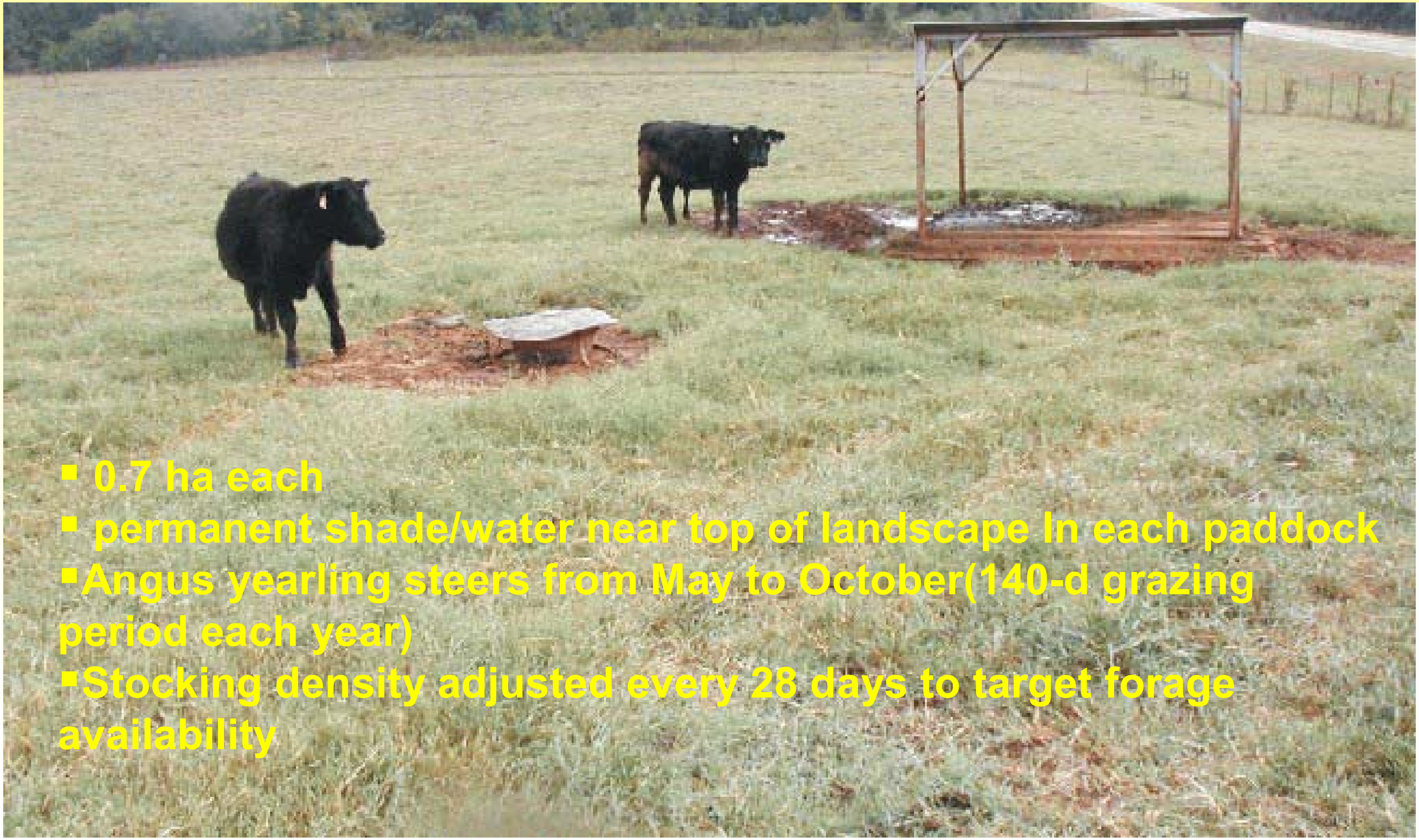
- ✓ 3 fertilization regimes (200 kg N ha^{-1} yr^{-1})
  - Inorganic only
  - Clover+inorganic
  - Broiler litter

  - Inorganic only
  - 1x broiler litter + inorganic, P based
  - 3x broiler litter, N based

  <u>Phase 2</u>
- ✓ 3 replications

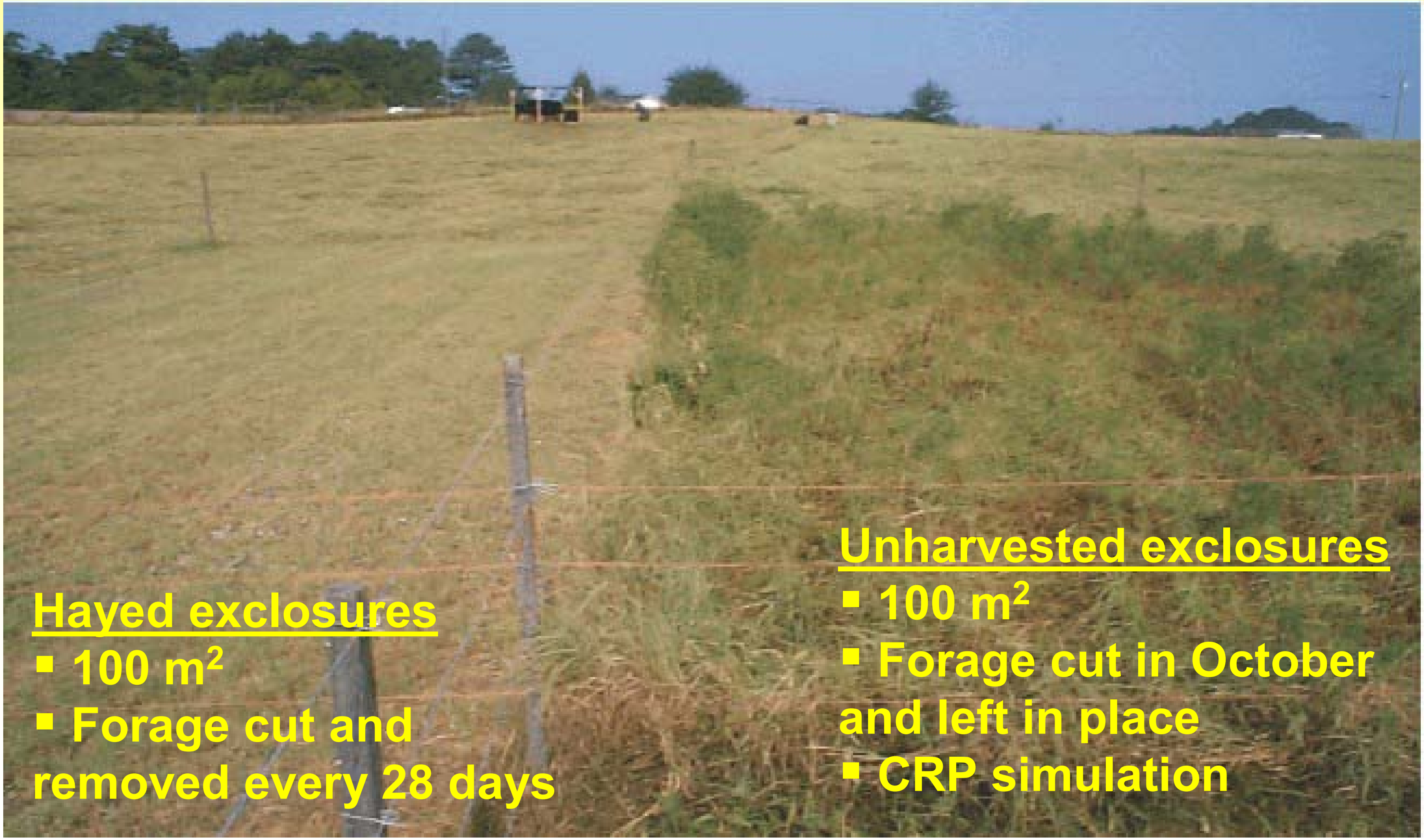
Salem Road Grazing Study

✓Grazed paddocks

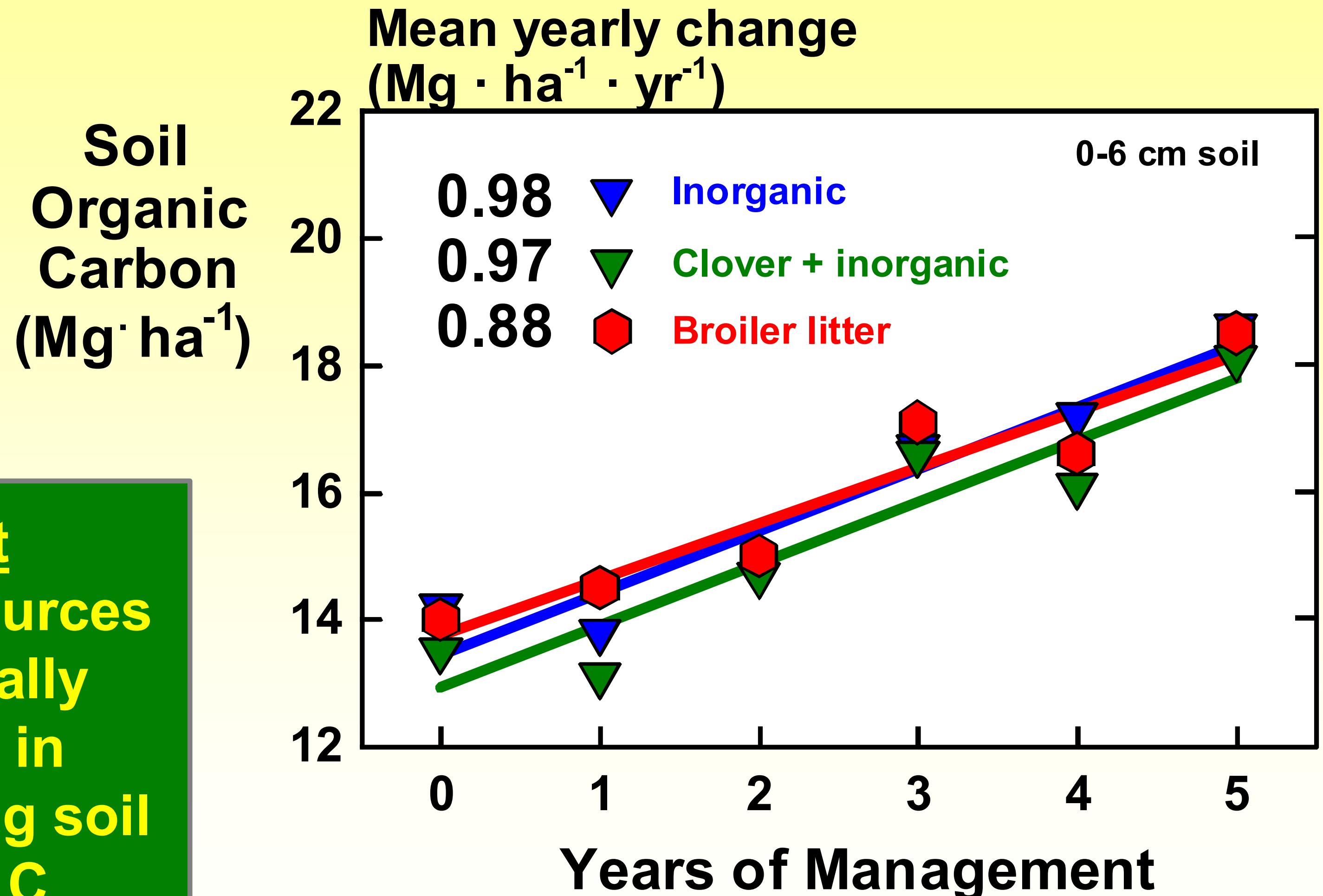


Salem Road Grazing Study

✓Exclosures



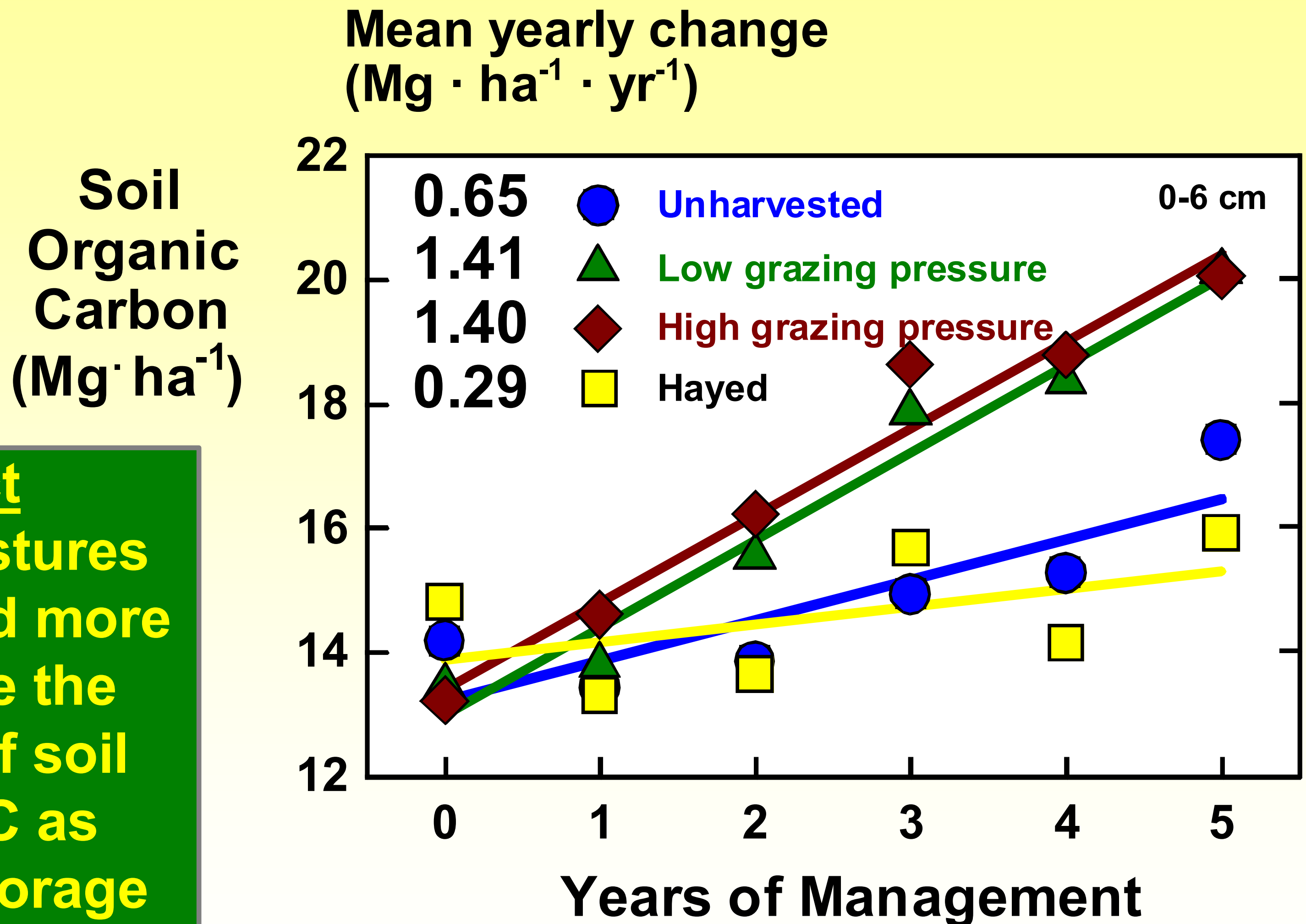
Salem Road Grazing Study



Impact
Fertilizer sources were equally effective in sequestering soil organic C

Franzluebbers et al. (2001) Soil Sci. Soc. Am. J. 65: 834-841.

Salem Road Grazing Study



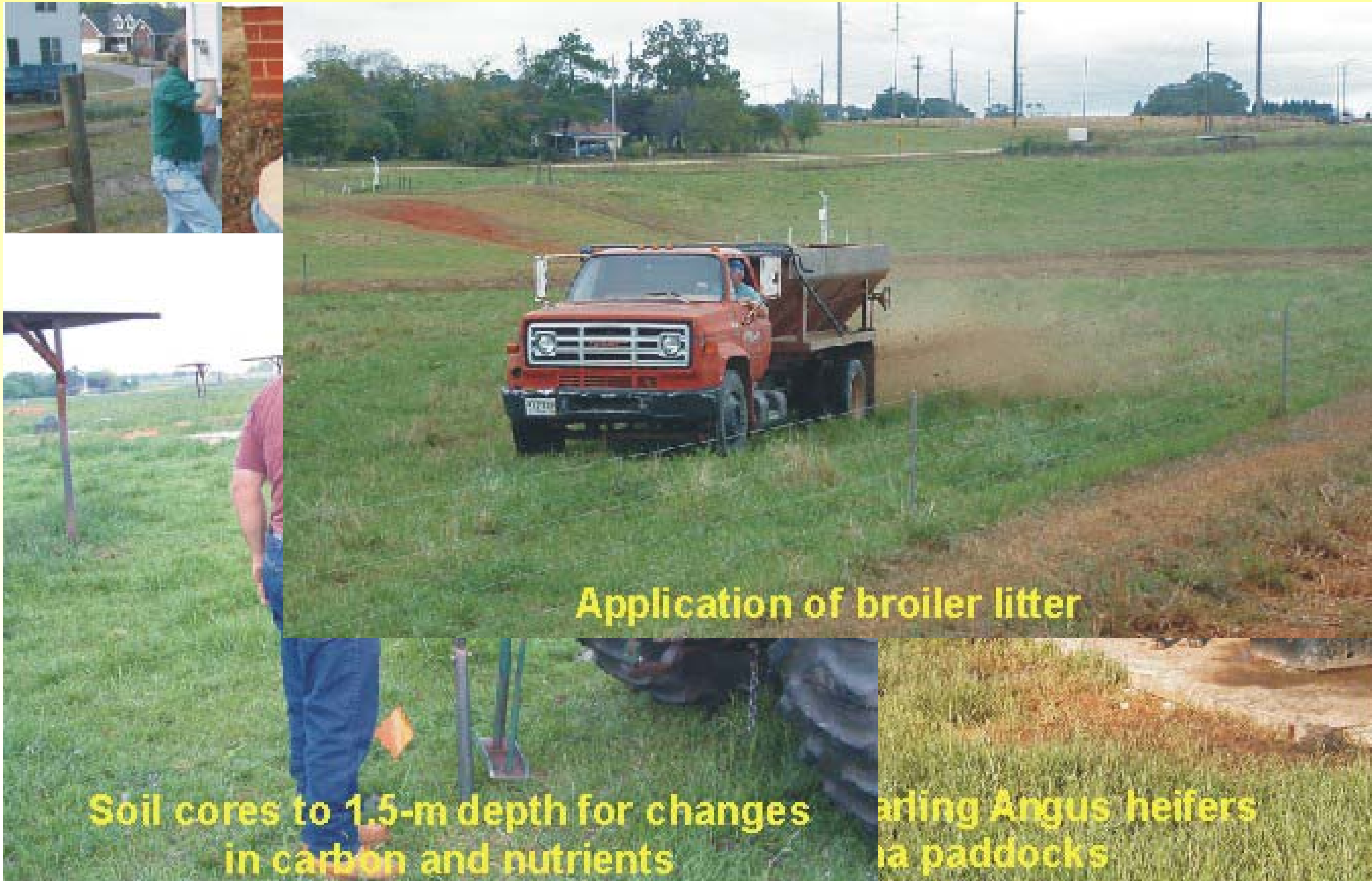
Impact
Grazed pastures sequestered more than twice the quantity of soil organic C as ungrazed forage systems.

Franzluebbers et al. (2001) Soil Sci. Soc. Am. J. 65: 834-841.

On-Going Studies in Watkinsville

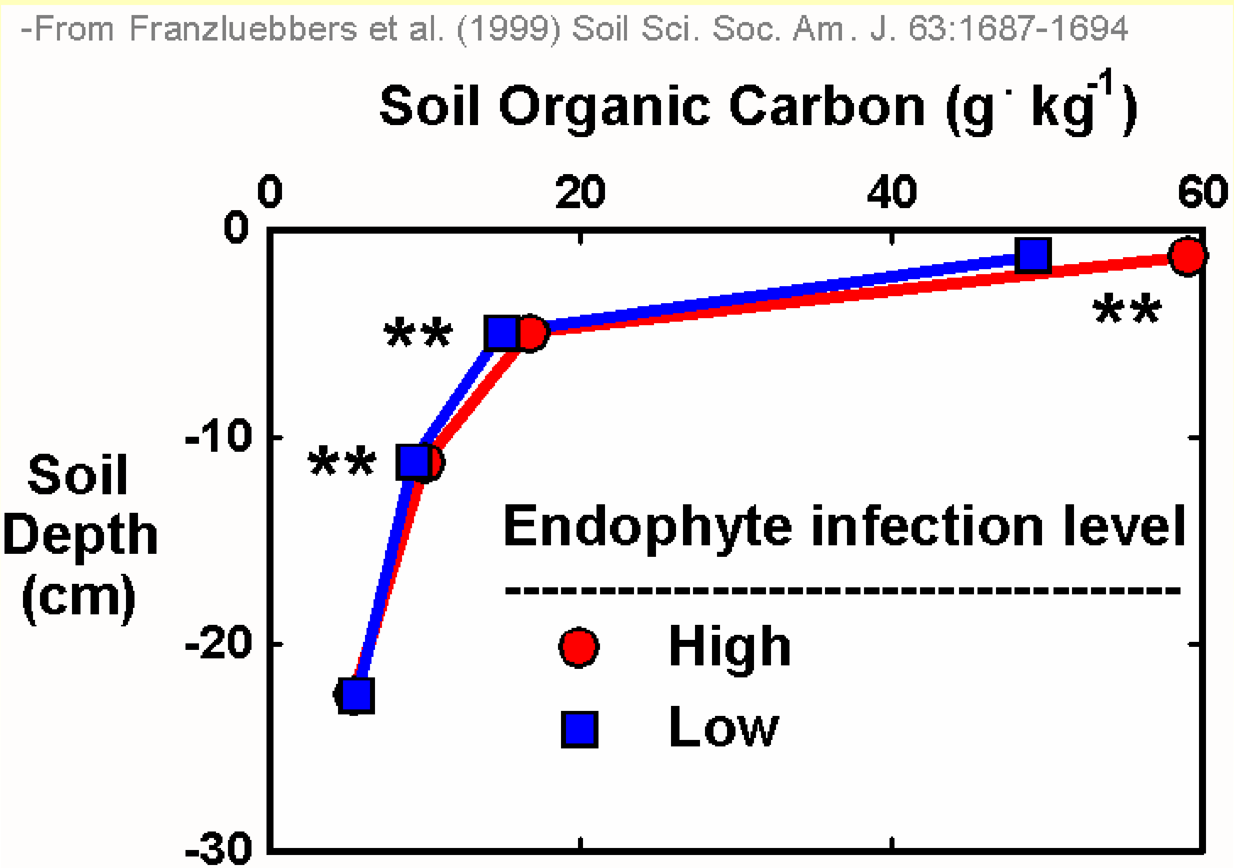
- ✓ Dawson Field grazing study, Watkinsville, Hog Mountain Rd
- ✓ 2002-2004, ‘Jesup’ tall fescue
- ✓ 3 endophyte associations
  - Wild-type endophyte
  - Max-Q endophyte (low ergot alkaloid)
  - No endophyte
- ✓ 2 fertilization regimes (180 kg N ha^{-1} yr^{-1})
  - Inorganic
  - Broiler litter
- ✓ 2 replications
- ✓ +2 hayed, Max-Q, inorganically fertilized pastures

Dawson Field Grazing Study



Dawson Field Grazing Study

✓ Soil organic C accumulated in response to endophyte



Specific mineralization of SOC ($mg\ CO_2\text{-}C\ g^{-1}\ SOC$)

Low		High
98	**	78
43	**	38
26	*	23
16		16

Dawson Field Grazing Study

✓ Isolation of endophyte affect on soil organic matter

Soil pool	E-		E+
Whole-soil organic C (Mg ha^{-1})	29.3	<	31.2
Particulate organic C (Mg ha^{-1})	12.5		12.4
Soil microbial biomass C (Mg ha^{-1})	1.3		1.3
Mineralizable C (Mg ha^{-1} 24 d^{-1})	1.3		1.3
Macroaggregate C (Mg ha^{-1})	31.1	<<	33.6
Microaggregate C (Mg ha^{-1})	1.7		1.8
Particulate-to-total C (g g^{-1})	0.42	>	0.39
Microbial biomass-to-total C (mg g^{-1})	45	>	42
Mineralizable-to-total C (mg g^{-1})	44		41

Accumulation of organic C in macroaggregates

Per unit of total C, biologically active fractions depressed with endophyte

Franzluebbers and Studemann (2005) Soil Sci. Soc. Am. J.

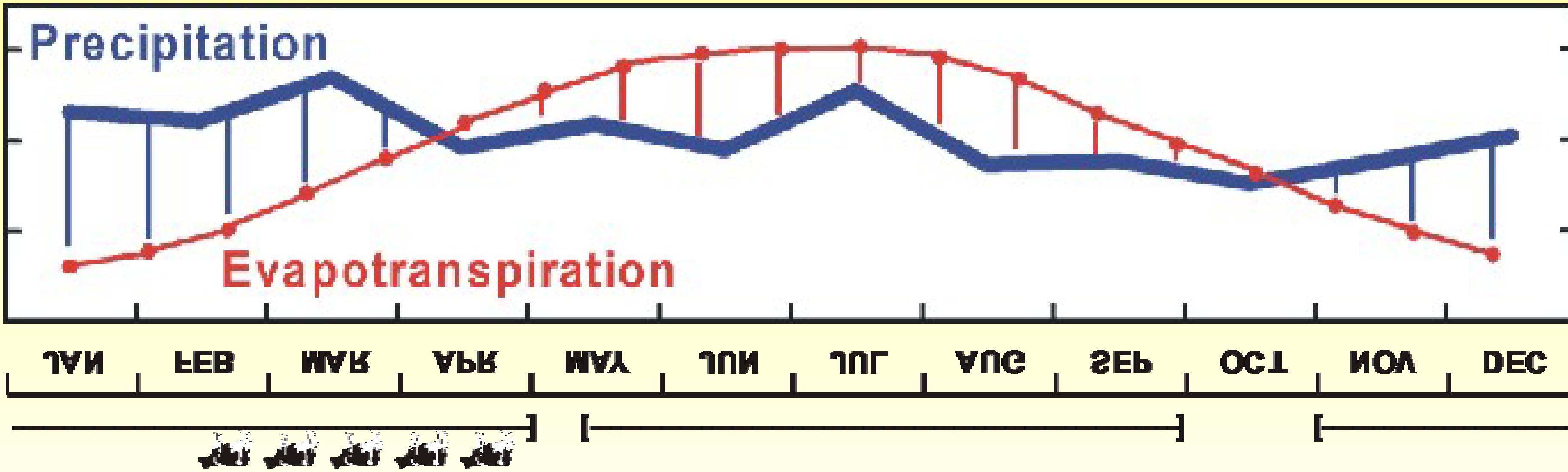
On-Going Studies in Watkinsville

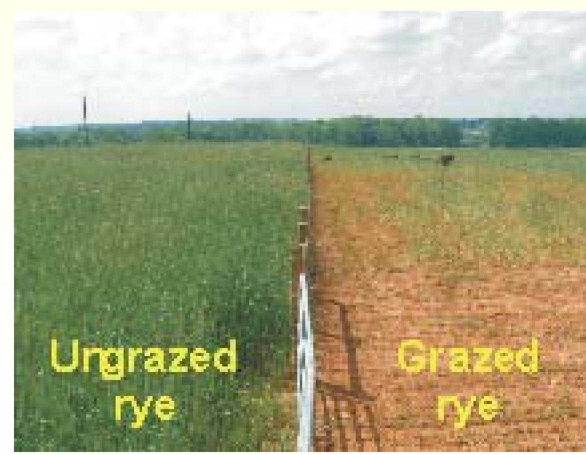
- ✓ Pasture-Crop Rotation study, Watkinsville, Govt. Station Rd.
- ✓ 1982-2002, tall fescue-endophyte associations
- ✓ 2002-2004, grain cropping with cover crops
- ✓ 2 cropping systems
  - Summer grain – winter cover crop (sorghum-rye)
  - Winter grain – summer cover crop (wheat – pearl millet)
- ✓ 2 tillage regimes
  - Conventional tillage
  - No tillage
- ✓ 2 cover crop management regimes
  - Unutilized
  - Grazed by cattle
- ✓ 4 replications

Pasture-Crop Rotation Study

Pasture-Crop Rotation Study

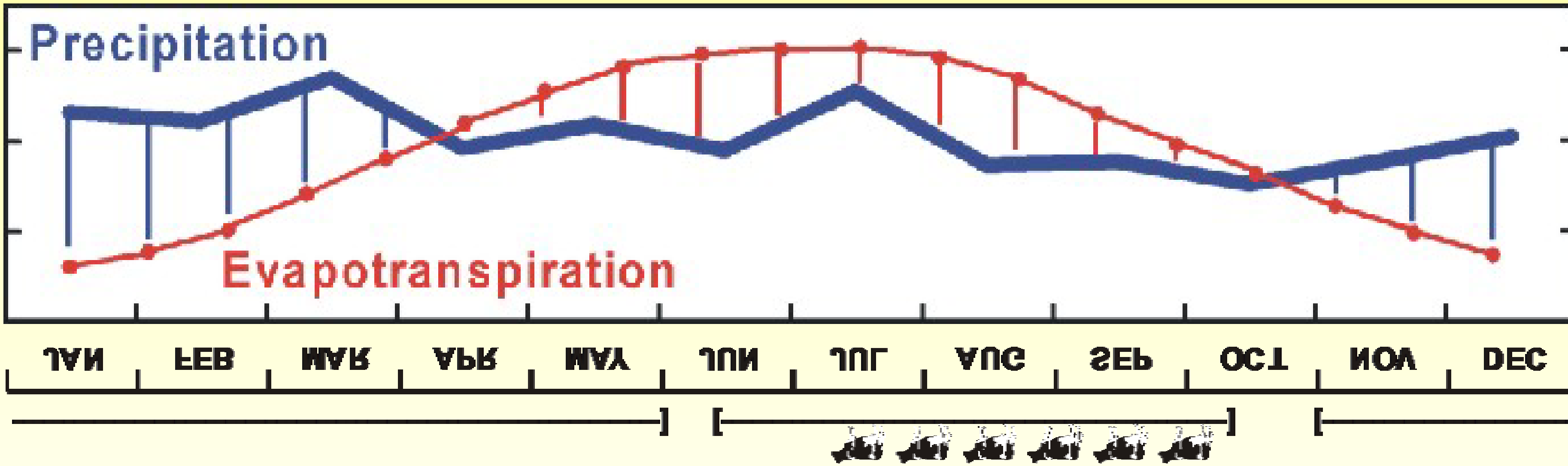
✓ Summer grain – winter cover crop

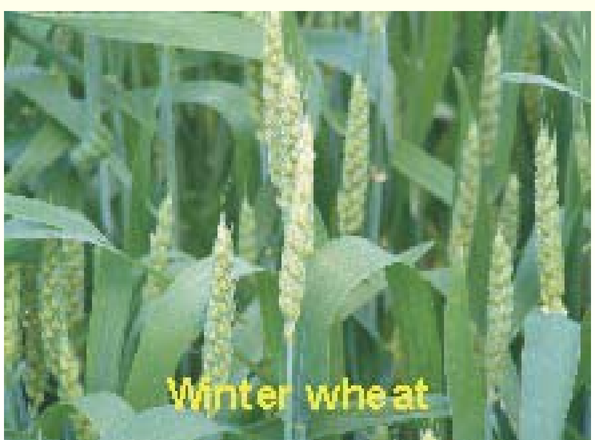


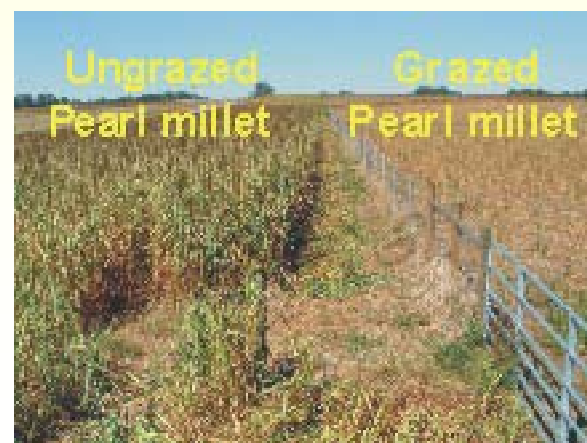


Pasture-Crop Rotation Study

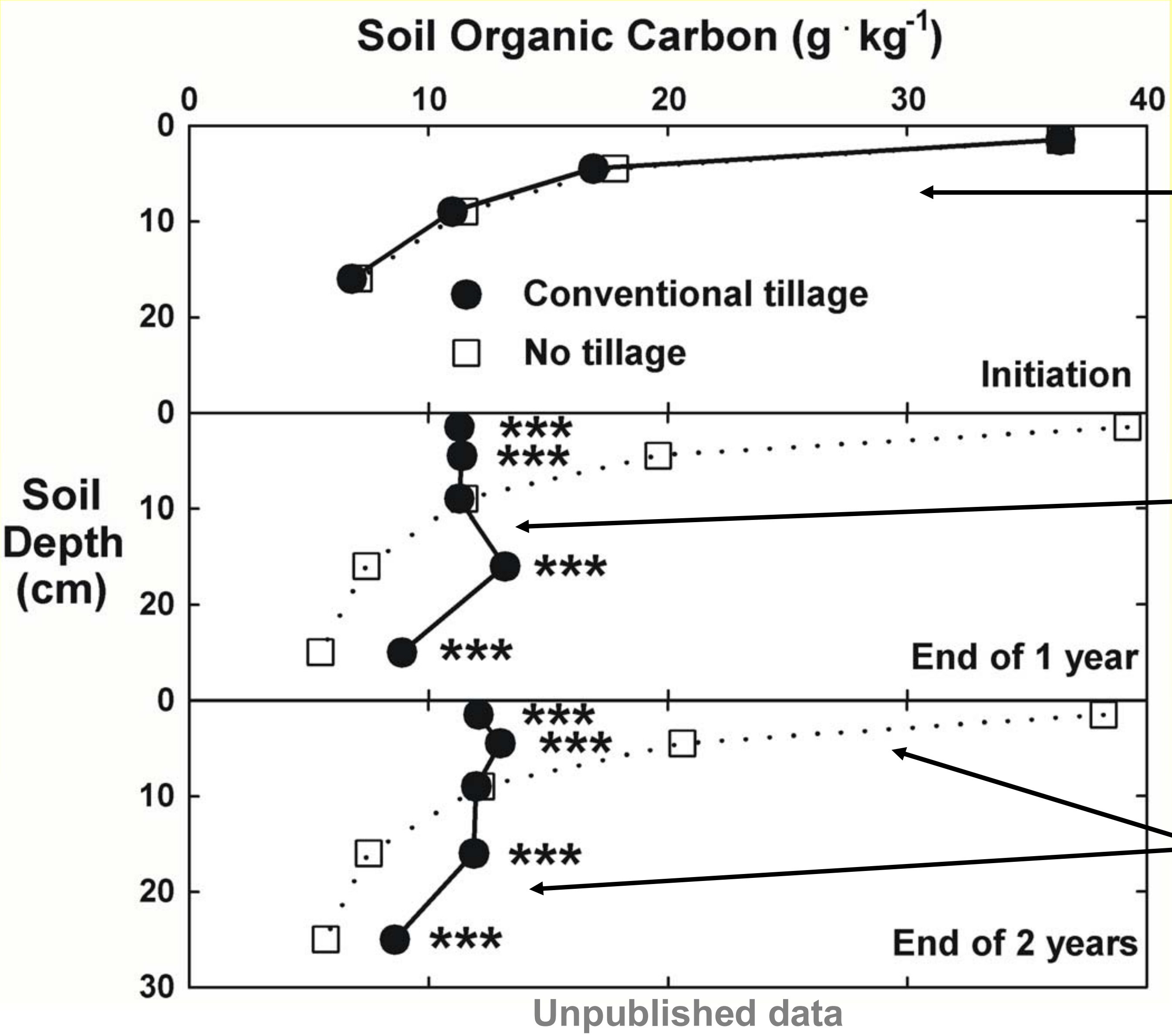
✓ Winter grain – summer cover crop







Pasture-Crop Rotation Study



Initially high surface C

Following inversion tillage, soil organic C became relatively uniformly distributed with depth

Soil organic C with NT was greater than with CT in the surface 6 cm, but lower than with CT below 12 cm

Pasture-Crop Rotation Study

	Soil		Surface Residue	
Time	CT	NT	CT	NT
0-20-cm depth	-------------------------	*Mg C ha^{-1}*	-------------------------	
Initiation	37.9	39.2	1.7	1.7
End of 1 yr	33.2 <<	38.9	0.2 <<<	2.2
End of 2 yr	33.9 <<<	40.2	0.5 <<<	4.0

- ✓ Carbon was immediately redistributed within the soil profile with CT, but not greatly mineralized
- ✓ Surface residue C was lost with CT, but accumulated with NT
- ✓ At the end of 2 years, total C stock (soil + residue) under CT was 5.2 Mg C ha^{-1} lower and under NT was 3.3 Mg C ha^{-1} higher than initial C stock (21% difference from initial level of 40.3 Mg ha^{-1})

Unpublished data

Conclusions

- ✓ Conservation agricultural systems can preserve soil organic C and help mitigate greenhouse gas emission
  - Conservation-tillage cropland
  - Pasture management
  - Pasture-crop rotation
- ✓ Agricultural contribution to net global warming potential requires more extensive research on N_2O emission and CH_4 flux in the southeastern USA
- ✓ Low fossil-fuel derived agricultural systems should be developed to further mitigate greenhouse gas emission